# Atlas of Insects Beneficial to Forest Trees

### VOLUME 2

BOHUMIL STARÝ ET AL.

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The forest represents in Nature a society of organisms, with its prevailing levels, and many years' growth of trees which form continuous stands. The basic element of this society is the green plants which form the organic mass — the phytomass. The many layers of forest trees enable the space and, therefore also the sun's energy, to be used much more effectively than in any other ecosystem. The phytomass in this primary production is used mainly as a construction material by the producer. During a year in the forests of the temperate zone, over an area of 1 ha, on average 13 000 kg phytomass (dry matter) is formed and wood is only a certain part of this. Also only a small portion of the phytomass is used as food by herbivores which are also a part of the forest society. They are a component of the secondary production which completes the activities of the plant producers. The herbivores prevail in this phase and, of these, the insects predominate, mainly in terms of the number of species and the total mass. It may be stated that about one half of the living species of insects in our country, i.e., about 15 000 species, is bound to the forest environment. The herbivores then become successively the prey of carnivores or of an environment where various parasites live. The zoomass of the bodies of these predacious animals (predators) and parasites forms the tertiary production of the forest societies, in which the plants, and the herbivores and their enemies bound to them, form the whole system which is kept in dynamic balance. Also, at a considerable reproduction quotient, the herbivorous insects are kept under control by the activities of predators and parasites. This hidden cycle, for which there is no information about harmful and useful insects, is not usually observed and is considered to be self-evident.

Apart from the effects of exterior factors such as, for instance, storms causing trees to be broken or blow down, drought and air pollution, damaged forests indicate the cumulation of optimal quantities of food and then the outbreak of bark— and wood-destroying insects. Man considers these insects which cause the deterioration of wood to be forest pests. Similar circumstances are found in artificially cultivated homogeneous and even-aged forest stands when microclimate changes are accompanied by a mass outbreak of defoliators. At the outbreak of forest pests, their enemies i.e., beneficial or useful insects, appear after a certain delay. The build-up in the population of beneficial insects lags a certain time behind that of the pest population. The population of beneficial insects can be formed following a disturbance in the balance of the forest society. At the development of problems in commercial forests, the forester is forced to apply all of the available methods of forest protection. He selects technical measures, including the use of insecticides, means of biological control or a combination of these methods. He naturally also pays attention to the activities of those insect species which he considers to be useful.

The basic classification in the feed realitonships between useful and harmful insects is the method of seizing the prey. A predacious

insect (predator) seizes and consumes part or all of the body of its prey which serves as food. To the contrary, a parasitoid lives in the body of its host, which is weakened or successively destroyed. A predator always destroys a considerable number of individual prey during its life. In contrast, a female of the parasitic ichneumonids (representatives of the family *Ichneumonidae,* and tachinid-flies of the family *Larvaevoridae*) deposits a single or a few eggs into the body of the host so that one or two hatched larvae destroy only one individual prey. Only females of the braconids and superfamily *Chalcidoidea* (representatives of the family *Braconidae* and *Chalcids*) deposit a larger number of eggs into the body of the host.

If the predator or parasite is bound only to a single species of herbivorous insect, this is known as monophagia. The development of a zoophagous insect is synchronized with that of its host. At the time of the reduction in the population density (latency) of the host, a reduction in the density of its enemy successively sets in. An oligophagous zoophagous insect is bound to the development of some similar species of its host. This makes it possible, at the time of a minimal occurrence of a host, for a zoophagous species to find allied host species in the necessary numbers. A polyphagous zoophagous species shows, in contrast, a very broad food spectrum since it can use as food most of the species of insects occurring in nature. Finally, a pantophagous species can consume, besides insects, also other arthropods, such as molluscs and worms. For the biological control of forest pests, oligophagous species (some ladybird beetles destroy aphids and scale bugs) and also monophagous species (the beetle, *Rhizophagus grandis* GYLL, is a predator of *Dendroctonus micans* KUG.) may be preferably used. Polyphagous insects often fail as a means of biological control because, naturally and during artificial propagation, their interest is spread to a wide variety of host species. An example is *Calosoma sycophanta* L. which at the beginning of this century was imported from Europe to the U.S.A. It was successfully acclimatized to North America but failed in the control of the gypsy moth which had been introduced, due to negligence, to the U.S.A. The failure of the control was the result of the availability of a wide variety of prey.

Another type of food specialization may be observed according to the requirements of the adults and the larvae of zoophagous species. Where both the adult and larval stages of the predator are bound to herbivorous prey, the victims are always higher in number than where only either the adult or its larva is carnivorous. Also only the larval stages of all of the parasitoids live on their hosts. So, for instance, the larvae of some species of the *Syrphidae* or *Chrysopidae* families destroy aphids effectively in nature whereas the adults of these above — mentioned families have other sources of food.

Herbivorous insect species develop in the forest environment on various organs of, or inside, trees. Their predators act accordingly: for instance, *Xylodrepa quadripunctata* L. pursues geometrid caterpillars on the leaves; some predators hunt insects which

have fallen out of the tree crown on to the ground (e.g., the ant, *Formica rufa* L.); others penetrate the galleries gnawed by bark beetles under the bark or by wood—destroying insects in the tree stems (e.g. the larvae of *Raphidia notata* F.). The females of some parasitoids often lay eggs deep into the sap of the tree directly into the bodies of the larvae which gnaw there (e.g., the ichneumonid *Rhyssa persuasoria* L.).

For the biological control of pests, the quantity of food required by zoophagous insects during the life of the adult or of the larva, as well as the ratio of numbers of prey to predator, need to be considered. A large *Calosoma sycophanta* L. consumes during its lifetime more food in the form of butterfly caterpillars than its allied smaller species, *Calosoma inquisitor* L. The former species is the predator of most importance. The specialization of larger species on larger caterpillars and of smaller species on minor caterpillars indicates the same behaviour in both. The evaluation of the natural fertilization ratio also shows a series of combinations. If the zoophagous and the pursued herbivorous species have the same fertility, the species of zoophagous insect that has a larger number of generations per year than its prey is more effective. If the zoophagous and the pursued herbivorous species have the same number of generations per year, the more effectively applied zoophagous species is the one which has smaller losses during its development than its prey, as by *Parasetigena agilis* R.D. and the nun moth, *Lymantria monacha* L. In contrast to this are the many species of parasitic braconids (family *Braconidae*) or of the allied family *Aphidiidae* which have a larger number of generations than the host. A predator which occurs in nature in larger numbers can be applied positively only if it is directed at a certain species of pest by its food requirements. However, this need not be the rule. The ant, *Formica rufa.* L, lives in very large societies in localities which have optimal conditions. Workers of this species capture mobile individuals of a wide variety of anthropod species in the vicinity of their nest and transport their victim to the nest where it serves as food for the larvae and adults. They destroy large quantities of nun moth caterpillars and can simultaneously destroy the pupating larvae, that have fallen to the ground, of *Parasetigena silvestris,* which is the main parasitoid of the nun moth. Under artificial and natural conditions, the ant nests prosper mainly in light pure pine stands, where drought, light and a supply of aphids of the family *Lachnidae,* living on pines with sweet exudates, which are eagerly collected by the ants, are the requirements for success. This was proved by numerous experiments in the Federal Republic of Germany, northern Italy, Poland and the U.S.S.R.

The biological control of pests uses knowledge not only of the taxonomy of insects but also of their bionomics, physiology and ecology. This work is particularly difficult because there is a lack of specialists investigating many groups of insects. This is especially true of the parasitic Hymenoptera and Diptera. The European book market lacks publications which provide a better

knowledge of useful insects and those which are available are mostly only short. A publication which, with the use of the present optical equipment, could provide coloured pictures of at least the most important insects which are considered to be useful is desirable. Therefore, a team of six authors have attempted to prepare this, selecting a total of 168 species which are important from the forestry point of view. Ass. Prof. Ing. Miroslav Čapek, D.Sc., prepared the outline of braconids (*Braconidae*), Dr. Josef Šedivý, D.Sc., the outline of ichneumonids (*Ichneumonidae*), Dr. Jiří Zelený, C.Sc., the outline of *Raphidioptera* and *Plannipennia*, and Dr. Petr Starý, D.Sc., the outline of *Aphidiidae*. The outline of the main forest ant species is the work of Pavel Bezděčka and the short outlines of scale bugs, Diptera, beetles and chalcid-flies are the contribution of Dr. Bohumil Starý, who also prepared all of the pen drawings and the 50 coloured tables which are an important guide to the text. This work could not have been done without team co-operation. The above-mentioned authors do not claim that their work is complete. The book provides only a selection of the most important species. The authors have tried to show all of those who are interested in forest insect life not only the variability of those insect species which forestry considers to be a useful aid in forest protection but also the difficulties which are a consequence of this variability and of the number of representatives of the individual insect groups.

The present publication will surely not only serve to better foresty students' knowledge of useful insect species but will also be a good guide for all those people working in forestry. It will certainly also increase the interest of the young in all schools and of voluntary enthusiasts in the protection of the beauty of Nature.

PRAGUE, 1 MARCH 1988          PROF. ING. DR. TECHN. ANTONÍN PFEFFER, D.SC.

Forests cover one full third of the area of Czechoslovakia. Their composition and species variegation are far from autochthonic since Man's influence has changed them for centuries. For this reason, the variety of species of insects living in the forest today has also changed in comparison with the original state and continues to change steadily. The information available only allows us to draw very rough outlines of the forest in the past. The irrepressibly progressive rationalization of living nature and the loss of the original state affect not only the forest and Man and his environment but also small animals living in the forest although we cannot be aware of this in our short lifetime. Also we do not strive to appreciate how much the reality of this seemingly negligible factor may influence the near future.

Each year numerous insect species, which until not long ago were still abundant, disappear from the forest and the treasure of Nature is deprived of them. In greatly altered biotopes, this is obviously connected with the disturbances of the food chains which have worked well for centuries. Other undesirable insect species have, in contrast, appeared in outbreaks, for instance, due to the introduction of pure spruce and, in this way, changes occur in the species composition of insects which are considered to be useful. These changes have mainly been found in the last few decades since applied entomology has become an important branch of forestry. Even the reduction and destruction of humus in erosion-threatened areas have not only had a considerable influence on the disappearance of plants dependent on humus but are also connected with the retreat of insect species which find shelter in rests of less disturbed landscape, in riparian stands on creeks and rivers, where pasture does not occur. In these places, numerous insect species are conspicuously concentrated from localities at higher elevations because they find food during the summer period, mainly on Umbelliferae. A wide variety of insect species is concentrated there; useful insects include braconids, ichneumonids, tachinid-flies and chalcid-flies, often in striking quantities.

The reliability of the use of beneficial insects during outbreaks of some harmful pests is often a subject of discussion for foresters who compare it with the influence of useful birds. It is known that, at the outbreak of some pests, birds do not stay in these localities for long even when feeding young and probably, in an effort to obtain a wide variety of food, search for other species of insects, often those which are less easily obtainable in the vicinity of the nest. Perhaps the reason for this is a dislike of eating only a single foodstuff. With useful insects, at problem outbreaks of pests, for instance, the pine beauty or nun moth, we observe the opposite: a concentration of insect predators, mainly ground beetles, scale bugs and parasitoids, particularly braconids, ichneumonids and tachinid-flies. This draws the attention of foresters who rightly speak about the greater reliability of useful insects. In connection with this, the following observation should be mentioned. During the frequent heavy defoliation by caterpillars

of the green oak leaf roller in the protected landscape of Český kras (Bohemian karst, Karlštejn—Koda), we observed a heavy parasitization of these pest caterpillars by chalcid-flies of the species *Brachymeria intermedia* NEES., although this parasitoid prefers the caterpillars and pupae of leaf skeletonizer moths in years when there is a low occurrence of the green oak leaf roller. At the local outbreak of the nun moth in the forests between Jihlava and Havlíčkův Brod, we found a conspicuous lack of interest in nun moth caterpillars of birds like the chaffinch, *Fringilla*, the thrush, *Turdus* and others. When feeding young, the birds preferred to collect less numerous caterpillars of other species on nearby shrubs.

At the present time, the position of modern integrated protection of forests menaced by pests is increasing in importance and not just because of the demands on the quality and quantity of wood being enhanced. During this century, wood has been highly priced. Besides this, it is steadily becoming more and more necessary to revise the consequences of the often imprudent, although sometimes seemingly effective, chemical control in forest biocoenosis. Pesticides, the chemicals used for forest protection, in the future will continue to be used, for example for the protection of agricultural crops, but more attention must be given to their use only in the most urgent cases. Excessively high doses of pesticides should not be used but they are. This is a relatively common phenomenon and is always harmful. Besides this, more attention should be given to the fact that harmful insects become more resistant to pesticides so that the chance of accidentally jeopardizing plants is often absurdly increased. In the future concept of integrated forest pest control, we may expect the population density of many harmful species to be regulated to a larger degree by biological control. More emphasis should be put on the importance of beneficial insects, and not just of forest ants which are given the most space in this publication.

The text and the pictorial section of this book divide beneficial insects into predators and parasitoids. The systematics commonly in use in entomological literature are not followed here. The first section is devoted to predators, particularly ants, the most frequent insect species found in forests. Then scale bugs, groups of predatory beetles, Neuroptera and Diptera are mentioned. The second part describes parasitic insects. For this reason, representatives of the order *Hymenoptera* are mentioned twice: in the first section, among the predators (ants) and, in the second part, among the parasitoids (ichneumonids, braconids, chalcid-flies and Aphidiids). Similarly, *Diptera* are listed in the first section under predatory species (robber-flies and lonchaeids) and then at the end of the text under parasitic species (tachinid-flies).

# CONTENTS

# PREDATORS
# ANTS

Organization of the colonies Ants (*Formicoidea*) form an important superfamily of important superfamily of Hymenoptera in the suborder *Aculeata*. Due to their specific social way of life, ants are the most remarkable insect group in the forest. For this reason, more space has been devoted to them in this book although the selection of species has had to be limited to the most important for forests (Tab. 1—9).

With the exception of the most wasted areas on Earth, ants inhabit all dry land, and not only this since, from deserts to high mountains, ants play a dominant role in most of the ecosystems on Earth. In absolute numbers, ants are the most abundant insect. This is the result of their social way of life which has made it possible for them not only to adapt themselves to an environment but also to transform actively the surrounding world according to their needs. Ants are very adaptable insects, indicating elements of mutual activity between their genotype and the environment. Most species of ants are omnivorous and predatory. Their predatory activity also continues after the food requirements of the society have been met. It is this supply behaviour which makes it possible for the ants to reach the high concentrations of individuals capable of using all of the available food sources. From the point of view of reproduction and the spread of ants, of basic importance are their high fertility, longevity and, only for a very short time, the occurrence of winged females which make the explosive growth of the population possible. The culmination of this is polygynous species (species with many queens in one nest) which prevent a local outbreak of competitive species of ants by establishing newly constructed nests and by occupying new regions. In this way, the population growth becomes unlimited. The spreading capacity of ants is potentially huge, particularly of species with suitable females (for instance, forest ants). With the spread of these species into new territories, their continual colonization does not occur only because other competitive species are present in the territories. Mutual relationships between competitive species are mostly territorial. Their areas of predation do not overlap. A nearly perfect saturation of all of the occupied biotopes by these species is ensured.

The wide spread of ants is also aided by their body structure: for example, the sting-transformed ovipositor; the robust broad mandibles which make seizure of the prey and also crushing of food easy and their use as a working tool (Fig. 1) for construction and defense possible; the jointed antennae are an excellent organ of smell and touch and for producing tactile signals during antennal speech; the eyes allow complete 360° perfect vision; the very mobile attachment between the head and the thorax is important for attack, defense and construction; and also the very mobile abdomen and running legs (pes cursorius).

The sting of the forest ants (subfamily *Formicinae*) is stunted but the venomous gland becomes hypertrophied and enables the accumulation of venom. During defense or attack these ants are able to spray this secretion up to a distance of 20 cm.

Ant eggs (Fig, 2) are white to yellowish in colour and very small. Those of forest ants do not exceed 0.75 mm in length. The eggs are of an ellipsoid form and are sticky on the surface. It is assumed that the larvae hatch in one to five weeks. They pass through five growth phases and are blind, whitish, relatively immobile and, during the younger stages, are covered by dense hairs which prevent the direct contact of their body with either the ground or other larvae. The body of the larvae is cylindrical, and narrows towards the head. The eyes and antennae are not differentiated but the mandibles are well developed. Depending on the microclimatic conditions, the nest and the food composition, the length of the development of the larvae takes from some weeks to some months.

The pupae are either bald (Fig. 2) as in the species of the subfamilies *Ponerinae* and *Myrmicinae,* or covered by a silken, oblong, oval, whitish cocoon (Fig. 3) as in those of the subfamilies *Dolichoderinae* and *Formicinae.* The cocoons are falsely called "ant eggs". Their formation is to a certain extent dependent on climatic conditions, since during prolonged rainy weather and when there is a deficit of good food, the spinning glands of the larvae become stunted. For this reason, we can also find bald pupae without cocoons in the nests of forest ants of the genus *Formica.* At the end of the pu-

Fig. 1 Worker ant carrying a cocoon

Fig. 2 Egg, larva, bald pupa of the worker and the fertile female

♀          ♂
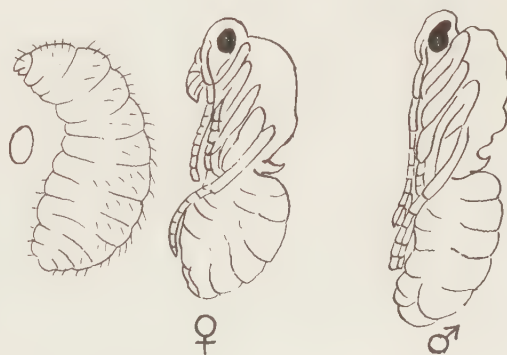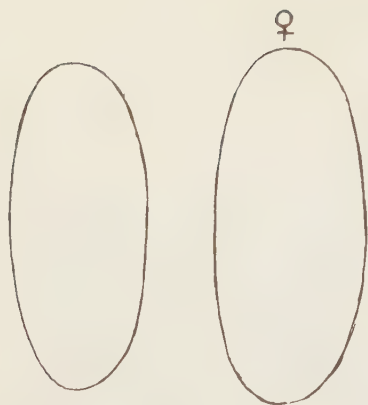
Fig. 3 Cocoons of the forest ant (of the worker and the fertile female)

Fig. 4 Worker of the forest ant

Fig. 5 Fertile female (queen) of the forest ant
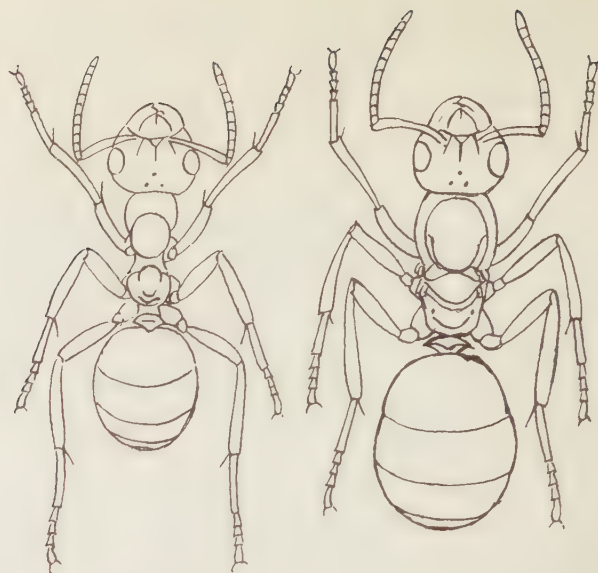
pation stage, the ant is not able to hatch independently. It succeeds only if older worker ants break the cocoon using their mandibles.

The fact that a nest has larger and smaller ants of the same species, which is a frequent phenomenon of many species, is not the result of a difference in age of the workers. It is due to the indigenous variability of the species and different conditions in larval development or the requirement of the society for the formation of different functional groups of workers.

The most frequent members of each colony of ants are the all-year-round workers. Workers are sterile modified females (Fig. 4). Worker ants like worker bees do all of the work in the nest. They differ from the larger fertile queens (Fig. 5) mainly in the structure of the thorax and abdomen. The thoracic muscles are atrophied and the thorax is, for this reason considerably reduced. In workers, the structure of the abdomen is influenced by the atrophy of the genitalia. To the contrary, their nervous system is more developed than that of the fertile females, mainly in that the supracesophageal ganglion is pronouncedly developed.

The number of workers in the nest depends on the species and the stage of development of the nest. Some species have only some tens of workers in the nest while other species (forest ants) have millions. The males live only a short time: their mission and life end after the nuptial flight. The males are well equipped for the fulfilment of their biological task, copulation. Characteristic for the males of all species is the robust vaulted thorax (Fig. 6) with well-developed wing muscles and robust wings with solid nervature. The head is, on the contrary, small (the mandibles are strongly atrophied) but bears large, convex eyes and long sensitive antennae. The males are, as a rule, dark coloured. Their number in the nest varies according to the species and the site conditions. With forest ants of the genus *Formica*, small and shaded nests mainly produce males while those which are large and well-exposed to the sun exclusively produce females. The reasons for this are to be seen not only in the lower temperature of the small and shaded nests but also in the deficit of food and also often in the impaired health of the nest. Males appear in nests periodically whereas at least one female is always present. The fertility and longevity of the females are

the basic requirements for the existence of each colony of ants. If the colony has only one queen, then it is monogynous. Monogyny is characterized by a monolithic nest which exists independently of other nests of the same species. The opposite is polygyny (nests with a larger number of queens) where there is the development of nest complexes which makes the use of the vicinity possible by increasing the number of individuals of the whole society and enlarging its territory.

The signal for swarming is given by certain climatic conditions, mainly air pressure, temperature and moisture. Swarming does not only occur in summer. Some species swarm in spring, others late in autumn. If the necessary conditions exist, the sexually mature individuals of certain species leave their nests to swarm at nearly the same time over a whole region. Copulation (Fig. 7) occurs during flight or after the pair have fallen onto plants or the ground. During the nuptial flight, each female is usually fertilized by several males. The nuptial flight fulfils two basic tasks: firstly, mixing of members of various nests of the same species during the flight prevents repeated copulation between members of one nest, i.e., between brothers and sisters; secondly, there is the possibility of spreading the species since, at swarming, young females are transported by the air streams over long distances. The males die soon after the end of the nuptial flight and copulation. Also a large number of the fertilized females perish due to various reasons and only a small number of them fulfil their function. The wings, which the females never need again, are discarded soon after. The fertilized female immediately erects a new nest. While searching for a suitable site, she often meets workers from another nest of her species. These workers adopt her and transport her to their nest as compensation for their old, already less fertile, female or she may be adopted by workers of polygynous nests to strengthen their society. However, if the female establishes a nest by herself, she excavates a chamber (in wood, under bark or beneath a stone) using her mandibles and deposits her eggs in it. She feeds the hatched larvae either with food obtained in the vicinity of the nest of from her own supplies or, during unfavourable weather, even with her own eggs. The first workers emerge after a few months, sometimes after a year. These differ from normal workers in that
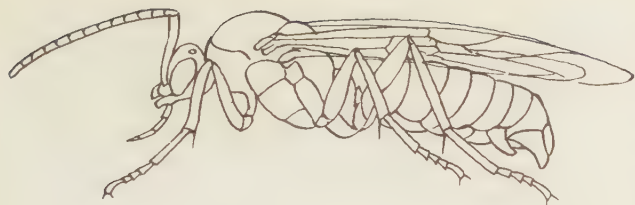
Fig. 6 Male of the forest ant from a side view

they are smaller since their development occurred under the influence of a food deficit. However, an immediate division of labour may occur among them: they ensure food supplies, establish further nest chambers and successively take over the care of the progeny, so that the queen only has to deposit eggs (like wasps and bumble bees). In some cases the first chamber is established by some young females of the same species together. In this way an alliance is developed which after the emergence of the first workers may, but need not necessarily, be cancelled.

Not all species of ants are able to establish new nests independently. Some are dependent on the aid of ants of other species and in this way they pass through the stage of the so-called preliminary social parasitism. This leads to the maximal shortening of the independent period of the fertilized female. Young fertilized females of preliminarily parasitic species (for instance, *Formica lugubris* ZETT.) must find an orphaned nest of an assisting species (for instance, *F. lemani* BOND.) where she replaces or kills the old queen. In an extreme case in such a nest, she may steal a small number of pupae which she transports into her own chamber. Assisting workers which emerge from these pupae then take care of the female and her progeny. In all of the above-mentioned cases the assisting workers perish in due course and are replaced by the progeny of the new female, thus ending the preliminary social parasitism.

A new method of enlarging the number of nests and extending the territory has developed with time. In polygynous species, this is achieved by the division of the mother nest and the separated sections becoming independent. Some females leave the nest with their progeny and occupy a rapidly established new nest forming an artificial swarm which, at the beginning, is fully dependent on the old nest but, in time, may become independent. This method of spreading the species has its drawbacks since the distance travelled by the artificial swarms from the mother nests are, as a rule, not very large.

The construction of each newly established nest is dependent on the species or genus of the ants. The specific conditions of the site are also of pronounced influence. Ant nests are very polymorphous varying from primitive nests in natural cavities in the soil or wood to an artificially constructed, highly divided nest. Some basic types are as follows: earth nests, combined nests, nests in wood and in cavities, and cardboard nests. The latter are only built by some species of ants. In our experience they are mainly built by the species *Lasius fuliginosus* LATR., which frequents parks and forests. Its monogynous nests are numerous in all types of forests in the lowlands and hills of Czechoslovakia. They occur mostly in the swellings of hollow trees, and are constructed from a grey-brown substance, which is very light and made by cementing fine wood and soil particles together. The nests in timber and beneath bark are much more primitive since they use the galleries and cavities left by wood-destroying insects and after the damage of the wood by fungal diseases. Such nests are established by many species of ants *(Liometopum* and *Dolichoderus)*. Other species build these nests only occasionally *(Myrmica* and *Lasius)*. More primitive nests are found in rock cracks and crevices or among stones. As a rule, there is only one nest cavity formed by caulking the gaps with soil particles. Such nests are characteristic of mainly small species of *Leptothorax* ants. Earth nests are established by many species of the genera *Myrmica* and *Lasius*. These nests are formed as a network of galleries and chambers excavated in the

Fig. 7 Copulation of the forest ant (left female, right male)

soil, one or more of which lead to the surface. The galleries lead underneath stones, where the largest chambers are found. The earth chambers are often connected with galleries leading into timber, beneath the bark of stubs, under stones, etc.

Combined nests are, in principle, earth nests with an artificially prepared superstructure made from plant and soil particles. Very large populations of ants of the species *Lasius niger* L. and *L. flavus* FABR. establish clay mounds of larger dimensions, reaching 60 cm in height above their nests. The relatively compact mound is interwoven with galleries and chambers. Some species of the genus *Formica* also erect similar nests.

The combined nests with a superstructure made from plant material, known to be the large nests of forest ants, are not, of course, as they seem to be, only cumulated mounds of needles; they represent a highly developed type of nest with a complex structure and many characteristic elements. Although they may have a series of modifications, some features are common. The base is always formed by a funnel excavated in the soil (Tab. 9). The soil excavated from the funnel forms an elevated mound and the bottom of the funnel is filled with rougher material, mostly short twigs and pieces of wood up to 10 cm in length. This inner cone of the nest hides numerous chambers for the development of the progeny. Other smaller chambers are found in the walls of the funnel and beneath it. The inner cone is covered by an external one, with a few chambers, made from finer material. Experiments with various coloured needles have shown that the nest material in the mounds of forest ants is continually being moved. Ants steadily lift soil and other finer material from the inner parts to the surface. The rougher materials which the ants cannot lift are successively accumulated and fall down lower in the nest under the weight of the upper layers. The inner cone is developed in this way. Constant circulation of the construction material mainly stops it becoming mouldy.

Some modifications to needle nests are characteristic of individual species of ants. For instance, nests of the species *Formica truncorum* FABR. (Tab. 6 and 9) are always supported by a dry stub, the cavities of which are also part of the nest. *Formica rufa* L. prefers to occupy hollow stems and stubs which it also successively covers with needles. In these cases, the structure of the inner cone is not so obvious and the earth mound around the nest tends to be small. With the species *F. polyctena* FÖRST., we find the opposite phenomenon because the structure is supported by heaps of old slash (Tab. 4). A robust funnel is excavated beneath the heap. The earth mound on top of such a nest is large and, in prospering nests, it is enlarged annually. The main reason why forest ants establish such complex and, from a construction point of view, challenging nests is to provide the optimal conditions necessary, for the successful development of the progeny. Forest ants are inhabitants of the zones of deciduous and coniferous forests and are forced to build their nests to ensure the economic use of the sun's energy and for safe hibernation. A mound nest presents an much broader surface area to the sun's rays than an earth nest. To increase this effect, the nests of forest ants are mostly exposed to the south and south—east. Further evidence to support the theory of maximal use of the sun's energy is the fact that nests in shaded sites are considerably larger than nests in open, bright localities. Besides the sun's energy, other factors are also active in the mound nests which make it possible for the forest ants to be independent of the thermic regime of the soil and air. Only perfect thermal regulation of the nest allows the rapid onset of the forest ants active season in spring and the development of sexually mature individuals by the end of spring.

During winter, the ants are concentrated in the winter chambers and the galleries in the deepest parts of the nest where the temperature does not fall below zero and remains within the range of 0.5 to 5°C. With the increase in the temperature gradient between the winter chambers and the nest surface, the ants successively waken and move to warmer areas. Those ants which hibernate in the upper winter chambers emerge first. After a further increase in the outside temperature, the ants leave the interior and move to the nest's surface en masse. They form up to a 20 cm layer of bodies on the southern slope of the nest. This is usual at 15°C. The ants are less mobile and the dark colour of their bodies allows them to warm rapidly. After a short exposure to the sun, they successively return inside the nest. In the nest's inner cone, some of the heat is released from their bodies and then they again return to lie in the sun. These heat bearers are, at the beginning, only a few in number but, in the evening, most of the ants release heat in the nest's centre; this contributes rapidly to the revival of biochemical reactions so that, during some warm spring days, the core of heat in the nest already reaches a temperature of 26 to 30°C, which is the optimal temperature for the development of the progeny. Ants regulate the temperature in the centre and other parts of the nest by having holes leading to the nest's surface and, using these, they strive to maintain the optimal temperature in the core independent of exterior climatic variations during the whole season.

Each nest possesses a territory which is interwoven by a network of ant communication sometimes with admirable construction features, typical for a number of species. During the construction of roads, the workers avoid large obstacles but they remove smaller ones and, in this way, a perfect communication network is embedded into the soil profile; often tunnels are developed.

The system of roads and their permanency depend on their purpose. The most frequent and long-lived are those between individual nests of a (polykalic) colony consisting of several nests. Each spring, the road is regenerated and agile traffic continues to use it throughout the whole season. At other times, the communications lead to permanent sources of food. In other cases, wide and heavily frequented communications lead to short-lived, but solid, sources of food and disappear after these sources have been exhausted. Also the size and boundaries of a territory often change depending on the food supply, or due to competition in the vicinity, or changes in the microclimate, of the site.

**Food.** Food plays an important role, mainly in terms of its quantity, in all forms of interspecific relations and in the life of each colony of ants. Most ant species have a characteristic broad food spectrum. Their diet consists of meat (proteins) and glycides (sugars).

The mutual ratio of these two components changes not only according to the species of ant but also with the annual season and food supply. Of fundamental importance is the protein which is mainly needed by the

larvae for their development. Much of this food is also consumed by the fertile females and a smaller quantity by the workers. Sources of this food are captured insects and other invertebrates and sometimes also the cadavers of insects and higher animals. On a smaller scale, ants gain such food by collecting seeds of various plants, from fungi and from plant sap. The percentage of proteins in the food of ants is very variable: for the genus *Formica*, insects account for 30 to 45 % of the food, plant sap for 5 % and seeds for 0.5 to 1 %. The remainder, on average up to 55 % of the diet, is formed by honey dew. This carbohydrate food is mainly a product of aphids and of scale bugs. Aphids are mainly represented by species of the family Lachnidae and of the genera *Cinara*, *Eulachnus* and *Schizolachnus*. These insects which suck up plant juices use only a small portion of this food and most (up to 78 %) of the undigested sugars (mainly melecitose and saccharose) are excreted from the body as sweet exudates. During one day, an aphid of the genus *Cinara* excretes 0.5 mg honey dew and, in warm weather, up to 8 mg. The dependence of ants on this source of food has caused the development of a mutually advantageous relationship called trophobiosis. During the production season, ants offer their aphids protection against predacious and parasitic insects and allow secure hibernation of the eggs of some aphid species in the winter chambers of their nests. Sometimes groups of aphids are even protected by a cover cemented from soil particles around the attacked parts of the plants.

Trophobiosis is known to occur in many species of ants, mainly of the genera *Lasius* and *Formica*, where its consequences can exceed the framework of the narrow relationship between the aphids and the ants; e.g., it stimulates the production of honey dew by aphid species which, in many cases, negatively affects the health of the plants (crop plants and mainly fruit trees). On the other side, the overproduction of honey dew makes the development of melitophagous insects in the given region possible. This mainly concerns a large quantity of parasitic Hymenoptera. The quantity of honey dew collected by one colony of ants during a season is very variable depending not only on the species of ants and aphids, and the number of individuals in the colony, but also on the climatic conditions. In some years, the production of honey dew is considerable while, in other years, it is negligible. Various observations of forest ants (*Formica rufa* L.) indicate the collection within the range of 200 to 500 kg honey dew per year by a nest which represents, on average, about 75 kg sugar. The producers of honey dew develop during the summer period and, thus, the maximal collection occurs at the end of summer, i.e. at the time when the colonies of aphids and scale bugs achieve their peak development.

Ants are predacious and ravenous insects. They bring food into the nests in time rhythms, the curve of activity of which has one or more peaks not only during the season but also often within one day. In spring and autumn, the curve of daily activity indicates one peak during the period of the highest temperature just before and after noon. In summer, when the highest daily temperatures occur, the peak in daily activity moves to the night-time and the collection of food also often occurs at its fullest intensity during the whole night. The composition of the ants' food changes according to the time of year. During the first days of spring, the ants use the reserves accumulated at the end of the previous season. However, early on this food is supplemented by the collection of dead bodies found within the territory of the feeding area since the active hunting and predation of live invertebrates is still less substantial at the low spring temperatures. The successive increase in daily temperatures increases the hunting activity with an increase in the number of victims. The accumulation of reserves provides a readily available food source which not only ensures the more rapid entry into the new season but also makes it possible to overcome the transient hunger periods during a year caused, for instance, by cold and rainy weather or chemical treatmenst.

**Social behaviour.**    If we talk about ants, we never think about individuals but about the whole colony. One ant is not able to exist independently. Its life, like that of any other social insect, is in a sense only that of the colony. The basic unit is the swarm established by the queen and her direct progeny. All of the activities of all members of the swarm are always of a social character and are directed to fulfil the needs of the whole colony. Most of the jobs are of such a character and scope that they are in no sense for an individual: the hunters' and collectors' predatory activity exceeds many times their individual demands while other ants build a nest which is of importance for the whole colony. The quantity and variability of the work and, thus, the establishment of specialized functions are dependent on the degree of the development of the whole colony. The larger the colony and the higher the degree of development, the greater are the growth and the number of functions ensuring the existence of the colony. Thus, the specialization of the workers is increased. The development of specialized professions and functional groups of workers is called polyetism. However, workers do not carry out only one type of specialized activity during their whole life. Like bees and other social insects, certain changes in profession also occur in the swarms of ants during the life of the workers. All these changes are directed by the requirements of the colony and mainly by the ageing of the workers (age polyetism). The youngest workers do not leave the nest and, at first, fulfil various functions inside it connected with the feeding and care of the progeny, and with cleaning, deepening and ventilation of the nest, as do bees. The workers leave the nest much later and assist with work either on the surface of the nest or in its vicinity. During this time, they gain experience and start to become acquainted with a wider environment, and successively transfer to groups of carriers: they transport construction material or food taken from hunters or collectors on the ant roads. It sometimes occurs during the movement along the ant roads or in the immediate vicinity of the nest that a young worker looses its orientation and goes astray. Such a deranged worker is carried back to the nest by an experienced worker. Each ant colony is a long-term institution and also individual workers reach a relatively great age. Thanks to this, each swarm contains several generations of progeny simultaneously,

Information is transmitted in various forms by various signalling systems. These systems may be tactile, kinoptical, acoustic or chemical. Workers moving from a food source to the nest regularly meet other workers going in the opposite direction. On meeting, they contact each other using their antennae. This is information exchange using the tactile system or antennal language.

The importance of the information is transmitted by the stress and frequency of individual contacts. Kinoptical systems are also included; they consist of the position and stance of the body and head. There is a series of positions representing attack, intimidation, request for food, offer of food, etc. It has been proved that many species of ants also use sound (stridulation) organs in the acoustic system.

Of main importance is the chemical system where signals are given by pheromones. Pheromones are hormones which synchronize and direct the life of the ant colony, ensure a correlation between all of the individuals of the nest and keep the harmony of all of the functions. Each ant excretes a whole series of pheromones. Some pheromones are alarm signals, others are defensive, territorial, tracing, marking, recognition, socially regulative, sexual and aggregation signals. Like the differences in the signalling functions of the pheromones, we also find differences in the form of their activities and the time of their effectiveness. Of short activity are the alarm, defense, sex and aggregation pheromones. After their excretion, these pheromones immediately affect a large number of individuals and then evaporate rapidly. To the contrary, tracing, marking and territorial pheromones left on shrubs, trees and soil give information on the boundaries of the territory in relation to the nest and influence the behaviour of only those individuals who come into direct contact with them. For this reason, their activity lasts longer, perhaps hours or days. This is, of course, also dependent on the local climatic conditions because high humidity, dew and rain remove the pheromones. The same disturbance of the pheromones is caused by mechanical treatments, for instance, heavy logging techniques. Socially regulative and recognition pheromones act permanently. These pheromones are spread among members of the colony continuously by the handing over of food and by licking. Food is handed over not only in the nest but also throughout the territory without interruption: a satiated ant feeds a hungry one and it, in turn, hands over a part of the food to other ants. This food exchange (tropholaxy) also concerns the queen and the larvae. A part of the exchanged food consists of various enzymes which ants produce, and the state and change of these biocatalysts affect many aspects of the life of the swarm, mainly the development of the larvae and the formation of the individual polyetic groups of workers. A similar influence is also indicated by an insufficient exchange of food. Hunger within the swarm puts pressure on the group of hunters and food collectors. A continuous exchange of food between members of a swarm is also of another basic importance: it serves to form and maintain the special odour of the nest which is an important requirement for the autonomy and independence of each colony. Ants, like bees and other social insects, differentiate between their own and foreign individuals according to a common odour.

A separate aspect of social behaviour of ants is their relation with other animals living jointly with them in the nest. Each ants' nest has some guests — myrmecophiles. They are excellently adapted to life in the ants' nest and live with their host either as true guests, symphiles, as tolerated guests, synoeketes, or even as guests giving rise to hostile reactions, synechthrans. Symphiles are guests which the ants feed, nurse and tend many times more carefully than their own progeny. The reason for this is the special exudates excreted at some point on the guest's body (the abdomen or the antennae). The place of excretion of such exudates can be recognized due to a wreath of golden yellow hairs. Ants eagerly lick this spot, although it sometimes has negative consequences, mainly the reduction of individual activity. A larger number of symphiles in one nest (mainly beetles from the families *Staphylinidae* and *Clavigeridae*) may disturb the life of the whole colony mainly by the fact that the larvae of the symphiles are predacious and destroy the ant brood without being disturbed. Ants are aggressive towards synechthrans in the nest but mostly without success because the latter are either more robust and bellicose than the ants or are more mobile. Synechthrans mainly include staphylinids and also some lithobiid genera.

The tolerated guests, synoeketes, are the richest in species and in the number of individuals. They include representatives of various groups of insects and spiders and mites. With all of them, it is characteristic that their relationship with the ants is mutually advantageous. They use all of the advantages of life in the security of the ant nest, take part in the removal of wastes, excrements and the remains of food, and often help ants with their personal hygiene. Some of them parasitize the ants' food or perhaps their brood. However, in all such cases the ant colony is never jeopardized. To the contrary, the ant colony may be negatively influenced by parasitization by numerous other species. Of the endoparasites, the most important are worms of the genus *Peloderma*, and the filariid *Gordius* which develops in the pharyngeal glands and the worm *Mermis* in the abdomen. In both the larvae and the adult ants, we find parasitoids such as some species of braconids and chalcid-flies and, *Myrmicinosporidium* the parasitic species of Protozoa. All these may be important factors in the ecological balance in the same way as some enemies from the outer environment, such as spiders, insects, birds and mammals.

The efforts of each ant are subdued to meet the requirements of the whole colony. Each colony is oriented to the fulfilment of three main tasks: establishing optimal conditions for the life of the whole colony, increasing the number of individuals and enlarging the territory of the species. The more numerous the colony the more complicated is its organization. Some species of ants are adaptable in such a way that they steadily move the upper limit of the maximum number of individuals as is the case with forest ants of the genus *Formica*. The basis of such unlimited growth is polygyny. Under good conditions, a swarm with many queens reaches such a high number of organisms that its further existence as a whole unit is not possible. The coordination between the individual groups of females ceases to function and their activities become uneconomical and, in this way, the mechanisms securing harmony between the individuals and the society are seriously jeopardized. At that time, partial swarms forms as separate organizational units. Each partial swarm must be vital, independent and have sufficient quantities of fertile females, brood and workers. The minimal number of workers is between forty and eighty thousand. The necessary conditions for the life of each partial swarm are space differentation or isolation of its nest and territory.

**Distribution.** In Central Europe we find a large number of various different species of ants. In Czechoslovakia alone, there are more than 100 species; most of them prefer steppe biotopes, either natural or agricultural. Of the remaining species, some are bound to the specific conditions of mountains or peat bogs or, on the contrary, to the artificial conditions of urban settlements. Only a small number of species are constant inhabitants of the forest, for example, ants of the genera *Camponotus, Leptothorax* and *Formica.* Besides this, there occur in the forest some species which are able to live in most biotopes and these are known as ubiquists. Examples of ubiquists are, for instance, *Lasius niger* L, *Myrmica ruginodis* NYL and *Leptothorax acervorum* FABR.

The composition of the forest myrmecofauna changes considerably according to the type, composition and age of the forest stand, the elevation above sea level and the geographical location. In southern and lowland regions, the composition is richer and more varied in species than under mountainous conditions.

1. Myrmecofauna of lowland forests. This group of forests includes all types of oak forests, from warmth-loving oak forests via pine (oak forests on sand to birch) oak forests. They occupy locations at elevations up to 350 m above sea level in warm and dry regions. The herbaceous and shrub layer is richly developed. Characteristic of these forests is a large number of species of tree ants which find plenty of opportunity to establish their nests in the branches, under the bark and in the stems and stubs of broad-leaved tree species (mainly oaks) and pines. These are species of the genus *Leptothorax* which, because of their small size and concealed lifestyle, are usually not observed. Other tree ants which are frequently represented are those of the genus *Camponotus (C. ligniperda* LAT. *C. fallax* NYL. and *C. truncatus* SPIN.) as well as the most decorative species of ant, *Dolichoderus quadripunctatus* L. Hollow and sick trees contain nests of *Lasius brunneus* LATR., *L, fuliginosus* LATR. and others. In lowland regions, the earth species are richly represented, including those of the genera *Myrmica, Tetramorium, Lasius* and *Formica.* Their nests are found beneath stones, moss and bark, in small earth mounds, in grass sods or fully free in the soil. The most frequent species are *Myrmica rubra* L. *M. ruginodis* NYL, *Tetramorium caespitum* L, *Aphaenogaster subterranea,* LATR. *Lasius niger* L, *L. alienus* Först., *L. flavus* FABR, *Formica fusca* L, *F. rufibarbis,* F., *cunicularia* LATR, *F. sanguinea* LATR. are a particularly important group in oak forests is forest ants of the genus *Formica.* In general, as in most other forest types, four species occur: *F. pratensis* RATZ. forming flat mounds (Tab. 3, Figs. a—c); *F. truncorum* F. forming stub nests (Tab. 6, Figs. a—c) not only on the borders of the forests but also often outside the continuous forest stand; *F. rufa* L (Tab. 1, Figs. a—c) and *F. polyctena* FÖRST. (Tab. 4, Figs a—c). Both of the last two species are the most frequently found directly in the forest stands where mainly *F. polyctena* FÖRST forms many large polykalic colonies. Besides the high percentage of tree ants, oak forests also characteristicly have a large percentage of representatives of the subfamilies *Dolichoderinae* and, on rare occasions, *Ponerinae.* These ants do not occur in forests at higher elevations.

2. Myrmecofauna of forests at mid elevations. These forests are broad-leaved and mixed stands of all basic types of oak (beech and silver fir) beech stand at elevations from 350 to 700 m above sea level. This region is climatically warm to slightly warm, very moist in places and has a relatively varied stand. The myrmecofauna of these forests is similar to that of oak forest stands, but is considerably poorer in composition: the species of wood and earth ants are reduced and the nests are concentrated on the borders of the forest stands and on other open sites. The genus *Leptothorax* is represented by the species *L. acervorum,* FABR. and *L. unifasciatus,* LATR. and the genus *Myrmica* almost exclusively by *M. rubra* L. and *M. ruginodis* NYL. (Tab. 8, Figs. d—f). Other representatives of the subfamily *Myrmicinae* are very rare. Of the genus *Lasius, L. alienus* FÖRST disappears and *L. niger* L. (Tab. 8, Figs. a—c) becomes dominant. A large change in the genus *Camponotus* occurs: the more demanding species disappear and only the wood-destroying ant *C. ligniperda* LATR. is found, which is replaced in cooler regions by *C. herculeanus* L. The earth ants of the genus *Formica* (subgenus *Serviformica*) are represented exclusively by *F. fusca* L. This ant is replaced in cooler regions above 600 m by the related species *F. lemani* BOND. Of the forest ants of this genus, the more frequently occurring *F. rufa* L. is listed. To the contrary, *F. pratensis* RETZ, nests occur less often. Another very frequent species is *F. sanguinea* LATR. (Tab. 7, Figs. a—d) and here and there, *F. exsecta* NYL. is also found (Tab. 7, Fig. e).

3. Myrmecofauna of forests at higher and mountainous elevations. In the complex of forest types of spruce, beech and beech stands dominating in mountainous regions at elevations from 700 to 1350 m above sea level, i.e., up to the upper forest limit, the herbaceous layer is very reduced, the region is climatically cool so the active season of the ants is short, the average temperatures are low and the total precipitation is high. For this reason, the more demanding species of ants disappear from this region and only adaptable species become dominant. Their nests are concentrated mainly on the borders of the forest stands, on clear cut areas and on other open spaces which are, for at least a certain amount of the day, exposed to direct sun radiation. In these places, we find colonies of the species *Manica rubida,* LATR. *Myrmica ruginodis* NYL. *Leptothorax acervorum* F. *Lasius niger* L, *L. flavus* F., *Camponotus herculeanus* L, *Formica lemani,* BOND., and *F. sanguinea* LATR. Also polykalic colonies of *F. exsecta* NYL. appear here and there. In the forest stands, there are frequently numerous mounds of the forest ants *F. rufa* L. and *F. polyctena* FÖRST. In some mountainous regions (the Šumava Mountains), two important species of ants are *F. lugubris* ZETT. (Tab. 5, Figs. a—c) and *F. aquilonia* YARROW. Their cone mounds also penetrate into the densest locations of mountain spruce forests. They also often appear above the upper tree limit. The genus *Formica,* mainly species living in mounds made from needles, occupies a characteristic position in the myrmecofauna of mountain forests.

4. Myrmecofauna of pure coniferous forest stands. The composition of these sometimes very huge forest stands does not always correspond to the original tree composition, elevation and site conditions. When the forests were being established, the foresters preferred Norway spruce and Scots pine so as to achieve the highest production in the shortest possible time. The

myrmecofauna of these pure spruce or pine stands is, as a rule, very poor in all regions and at all elevations above sea level. The forest ant, *Formica rufa* L., dominates. However, in these pure stands the best adaptation is achieved by the species *F. polyctena* FÖRST. which often forms very strong polykalic colonies. Mounds built by this species achieve huge dimensions in spruce complexes.

Due to ageing and mainly economic measures or after large windfalls, the conditions of individual sites successively and radically change. This results in corresponding changes in the composition of the ant populations. The species which disappear are replaced by others and a change in the interspecies associations occurs. With rapid changes as, for instance, due to clear cutting, there may be a total change in the species composition often accompanied by a preliminary penetration by species of non-forest ants. Nevertheless, forest ants of the species *Formica rufa* L. are able, to a certain degree, to adapt themselves to negative aspects of large environmental changes and remain at the site of their occurrence. Only vast and permanent changes in local conditions are a reason for their movement or it may also be due to the destruction of their association. Even the stability of the forest ants, the longevity of the swarm and the concentration of individuals are carefully evaluated during the assessment of the usefulness of ants in forestry.

Usefulness. Ants are an active factor of each natural, original and altered environment. Their importance has been known for a long time and some species have been studied deeply and thoroughly. In spite of this, it is not possible to decide explicitly whether a species is either only useful or also harmful since usefulness and harmfulness are relative conceptions. The same species may be, under some conditions, useful and, under others, harmful. So, for instance, the nests of the ubiquist ant *Lasius niger* L. are not welcome in gardens, orchards, and forest nurseries because the trophobiosis existing between this species and aphids and scale bugs causes harm by weakening and destroying cultivated plants. To the contrary, the nests of the same species in forests and on clear cut areas contribute to an important extent in the formation and regeneration of forest soil and positively influence the development and production of forest stands. For the assessment of the usefulness of ants, it is necessary for this reason to start with the environment in which they live and this is where we should evaluate them. *Formica rufa* L. occupies a dominant position in forest associations. Many experts have tried in the last fifty years to evaluate objectively the importance of these ants for forestry. The results of their research represent, of course, a wide scale of evaluation starting from the exaggeration of the importance of these ants for forestry to the full negation of any positive influence on the state of health of forest stands. Most of the work was from the beginning already influenced by efforts to prove clearly whether these ants were or were not able to regulate harmful insect populations in forest associations. However, this one-sidedness misrepresented the results obtained.

Although the predatory activity of forest ants is important, it is not the only activity which influences the forest environment: their trophobiosis with aphids as well as their relationships with vertebrates and plants are also of importance. Their predatory activity secures

sufficient protein food for the development and nutrition of numerous progeny. Many associations have a high consumption of food and, for this reason, their workers are aggressive to all forms of life in their food area. It has been proved many times that, in the case of higher predators, their predatory activity results in the improved health of the prey populations since the victims of their attacks are mainly sick and less mobile, or already superannuated, individuals. With forest ants, we find contrasting circumstances since they attack only healthy, mobile individuals whose activity irritates the ants. Forest ants do not attack relatively immobile, sick or parasitized individuals as a rule or carry them from necessity. They hunt all active insects and other arthropods and do not differentiate between useful and harmful insects. During the period when harmful insect populations are small, the composition of their prey is very varied. It contains harmful, useful and indifferent insects. The ratio of these components is not constant and it is equivalent to the supply. If the population of a species of insect in the forest stand increases, its supply as a food also increases as does its share in the prey of ants. Ants limit the borders of their food area according to the plentifulness of food. On average, the radius of activity of their workers may exceed a distance of 100 m from the nest; as a rule, it does not exceed 50 m so that the effective inhabitation of the forest by forest ants would require two to three nests per ha. Such an inhabitation represents a 100 to 150 kg biomass of ants. To supply the food requirements of the nests at such a concentration, the workers must gain daily about 1 kg protein food. With respect to the fact that forest ants also fulfil other functions in the forest and that they take part, together with other predators and parasitoids, in the destruction of harmful insects, it is necessary to acknowledge their importance at a lower level of the population, i.e., we also have to acknowledge the positive importance of an individual nest.

It is not easy to estimate how many insects are destroyed by one nest of forest ants during one year. It is estimated that a nest of mean size of the species *Formica rufa* L. consumes 8 000 000 individual insects. Individual observations mainly from the last few years are very different. None of the hitherto used methods can give an accurate answer since it is not possible to find out reliably how much of the prey is processed directly outside the nest and may be transported as a liquid food in the ants' stomachs.

In the estimation of the influence of forest ants in the destruction of pests, attention is often given to the fact that, although forest ants are able to affect and may destroy defoliators, they do not have any effect on bark beetles. The reason for this is the concealed lifestyle of these beetles. With the exception of the period of swarming and flight onto trees, forest ants do not meet them. We have to pay attention also to the low mobility of bark beetles and their low irritability to the ants and to their solid chitinous body covering. Nevertheless bark beetles are recorded as being part of the food of forest ants to a small extent.

In their relationships with other animals, an important place is occupied by their trophobiosis with aphids. This activity may have favourable consequences for the healthy development of the forest. Forest ants form trophobiotic relations only with those species of aphids which have no wax cover on their body (representatives

of the family *Lachnidae*). Long-term research has shown that the suction of trophobiotic species of aphids in the environment of the nests of forest ants does not impair the health of the trees and does not reduce their increment. The only risk with trophobiosis is an excessive production of honey dew which, under favourable conditions, forms a continuous layer on needles and leaves thus reducing transpiration and enabling the growth of mycoses. The availability of honey dew gives ants the possibility of maintaining a high concentration of individuals during a period of a small supply or even a lack of protein food and contributes to an increase in the number of parasitic insects. More than 200 species of forest insects, mainly Hymenoptera and Diptera, use honey dew as a food supplement for adults, which favourably influences an increase in their fertility and also the length of their life. During the last few years, experts have assessed the importance of trophobiosis of forest ants for bee keeping. Due to increased industrialization of the landscape and the use of chemicals in agriculture, bee keepers cannot find sufficient suitable sites in open terrain and, for this reason, they locate bee houses for a considerable part of the season and often for all of the year in forests where one of the basic sources of collection for bee colonies is honey dew. For this reason, the annual collection of honey dew by bee colonies is considerably greater in regions with a high occurrence of forest ants.

Also the relationship of forest ants with vertebrates should be assessed very positively although it is established on opposite grounds. Forest ants form a considerable part of the food of wood grouse and woodpeckers. Forest ants and their pupae are an important part of the diet of chickens of the species *Tetrao urogallus*. In forest stands where forest ants occur, the numbers of some woodpeckers, mainly the black and green varieties, are sometimes increased by up to even three times. During the so-called hungry periods (those of long rains, cold or large-scale chemical treatment of forest stands), forest ants are often an important compensatory source of food for many species of songbirds.

Ants often complete their diet with seeds. There is a series of plants seeds which are distributed by ants. They consume only the oil and sugar components of the elaiosomes without harming the germination of the seeds. This concerns mainly plant species in the lower layer of mixed forests (all violas, fumitory, liverwort, spurges, primrose, snowdrop, etc.). A large quantity of seeds is transported in this way to other places and some of them are used as a construction material (a phenomenon known as myrmecochory). The rich herbaceous and shrub layer near ant nests is not usually jeopardized by defoliators which improves conditions for birds and game.

Forest ants are an important soil-forming factor. The huge numbers of ants and their progeny, the quantities of reserves and the waste in the nests require, a large network of chambers and connecting galleries. Where the soil profile permits it the system of galleries often reaches more than 1 m in depth (Tab. 9). In the mountains on shallow podzol soils, most of the chambers are in the inner cone of the nest. On deep soils with a high exposure to the sun, mainly sands, the upper construction is greatly reduced and all of the chambers are relatively deep in the soil. The workers move a considerable quantity of soil during the construction and contin-

uous enlarging and preparation of the nest. Their activity is also visible from outside, mainly in the spring and summer months, due to the growth of the nest wall, which has the form of a clay ring at the base of the mound.

For other selected species of ants in Central European forests, common aspects of earth nests include fewer swarms and a greater density of nests on suitable sites. *Formica fusca* L. inhabits nests beneath stones, bark and moss and in decaying wood. Their weak polygynous swarms are of only some hundreds of individuals. The importance of these ants is mainly their soil-forming activities. Besides this, the new and weak nests of this species are one of the possible means of establishing new forest ant nests in the form of preliminary social parasitism.

Nests of other species, mainly *Lasius niger* L. and *Myrmica ruginodis* NYL. are found in similar places. Their density is high on favourable site. On forest borders or on clear cut areas there can be two thousand nests over an area of 1 ha. Changes in the vegetation are the reason for the frequent migrations of these species.

Ants of the genus *Myrmica* also move many times during a year. Ants of the above-mentioned genera transfer up to 3 % of the forest litter and upper soil layers annually in light forest stands. In this way, they enrich the soil nutrients and improve the soil structure. Also the influence of ants on stub decay is very important. After felling, the bark of the stubs is softened by the mycelium of various fungi and by the activity of bark beetles and, in this way, is prepared for ant nests. Many species of ants spread onto the clear cut area relatively rapidly and soon occupy the majority of the stubs. During the ensuing years, changes in the occupation of the stubs occur. During the first stage, as long as the bark is still attached to the wood, the stubs are occupied by the species *Leptothorax acervorum* FABR., *Camponotus ligniperda* LATR., *Formica sanguinea* LATR., and *F. truncorum* FABR. During the second stage, when the bark becomes separated from the wood, the myrmecofauna is enlarged by other species (*Myrmica ruginodis* NYL., *M. rubra* L., *Lasius niger* L. and *Formica fusca* L.). As the surrounding vegetation grows, the microclimate becomes successively colder and moister and stubs become covered by moss. For this reason, warmth-loving species of ants leave the stubs. During the last stage, the humified and moss-covered stubs are occupied only by the nests of *Myrmica ruginodis* NYL. All of the above-mentioned species of ants successively accelerate the humification of the stubs and simultaneously retard the development of wood-destroying insects. The soil-forming and humification activities of earth ants are very important for extreme forest and non-forest sites, mainly near water sources, on peat-bogs, on water-logged and acid soils, and on rocky slopes and broken stones. Research on forest ants (GRIMALSKIY, ZACHAROV AND MALISHEVA) was connected in 1971 with the "Action Muravey" which was accepted by 60 regional administrations. On all these sites, artificial afforestation is very difficult, and sometimes absolutely impossible. The natural regeneration of the forest stands is also considerably affected by ants. Seedlings grow on the majority of the former sites, and on the existing nests, of earth ants where they find optimal conditions for growth.

Research and protection of forest ants. At the out-

break of pests a long time ago, foresters paid attention to "the green islands" on the sites where forest ants did not start before the 1930's in Germany and this was mainly due to K. GÖSSWALD who was the first to prove the multiple positive effects of forest ants on the regeneration and the hygiene of forests. He was the first to use the rearing and introduction of fertilized forest ant females and also directed the large movement of ants into territories menaced by periodical pest outbreaks. One of the first of his co-operators was MARIO PAVAN who, in the 1950's, successfully organized the protection and the use of forest ants in Italy. He mainly directed the movement of the ant *Formica lugubris* ZETT. from the Italian Alps into the regions of the Apennines devastated by outbreaks of *Thaumatopoea processionea* L. In the 1970's, a large number of nests of the same ant were moved to Canada. The inventory of forest ants in Bulgaria, Romania, Austria and Switzerland started by 1960; it continues today and is connected with an excellent programme for the protection of forest ants. In the U.S.S.R. research on forest ants started during the

1950's when, after the end of the Second World War, forestry was intensified not only to introduce modern silvicultural methods but also to increase the protection of forest stands. The inventory was carried out over an area of over 7 million ha and about 4 million forest ant nests were mapped.

In the Č.S.S.R., Law No. 40/1956 on State Nature Protection included (in Public Notice No. 80/1965 Code) forest ants in the list of protected animals. However, it was not before 1976—1977 that the first practical experiments were conducted on the protection of endangered nests of forest ants at a planned surface coal mining site in northern Bohemia. In this way, action for the protection and the use of forest ants was established in the Czech Socialist Republic. It was named „Action Formica" and was proclaimed by the Czech Union of Nature Protectionists and the Ministry of Forestry and Water Conservation of the Č.S.R. The target of this action is to preserve the state of forest ants in Czechoslovakia and to use them in integrated forest protection.

## SCALE BUGS

Scale bugs belong to the insect order *Heteroptera*, representatives of which have stinging and sucking mouth parts, a highly chitinized body, jointed appendages and a fixed head. The rostrum is near the body on the ventral side of the head and, during sucking, the whole of it shifts forward. The forewings act as covers for the thorax and abdomen. Their metamorphosis is imperfect: the larvae develop flying wings and wing covers successively. Although scale bugs occur frequently among the forest insects, their way of life has been very little studied. It is only during recent years that more attention has been paid to them. The size of this book permits the description of only one of the most important species, *Picromerus bidens* (L.) (Tab. 10, Figs. a—d). At a mass outbreak of the nun moth, this species is frequently found and foresters rightly consider it to be useful. The adults and larvae attack the caterpillars of the nun moth and suck on them. The caterpillars lose interest in food and soon die. *P. bidens* L. is often an important factor in the destruction of the larvae of the pine saw-fly, *Diprion pini* L., and other saw-flies.

Of the same importance is the related species *Troilus luridus* F., which is the same size and also belongs to the family *Pentatomidae*. It differs from *P. bidens* L. in that the side margins of the transversely wrinkled shield are broader toothed at the front and do not have pronounced pointed protrusions. Also this species hibernates at the imago stage and, during the summer, main-

ly lives in the crowns of trees and on shrubs. The same way of life is found in the scale bug *Pentatoma rufipes* L. which feeds not only on insects but also occasionally on fruits. This bug is common on raspberries and sucks up the raspberry juice.

There are many species of scale bugs, mainly from the families *Miridae* and *Anthocoridae*, which are predators of harmful insects but no attention has been paid to them in terms of the biological control of forest insect pests. The following species should also be mentioned: *Anthocoris nemorum* L., *Phytocoris tiliae* F., and *Philophorus clavatus* L. These species attack small insects and mites. Only 4 to 5 mm long, the bright brown *Anthocoris nemorum* L. occurs regularly among colonies of aphids on the mountain ashes *Sapaphis sorbi* KALT. and *Schizoneura lanuginosa* HTG. (mainly in the cavities of the leaf galls of the latter). The aphid nymphs often frequently occur in the galls during summer. By July, the *Anthocoris nemorum* WIEL. have already often fully destroyed the whole population of aphids and will finally also suck on the remaining drops of honey dew. *Calocoris ochromelas* GMEL. and *Sthenarus roseri* H.S. play a considerable part in the destruction of the caterpillars of the green oak leaf roller *Tortrix viridana* L. during a mass outbreak. The scale bug *Philophorus cinamopterus* KBM is often found on the coccoidea of conifers.

## GROUND BEETLES

Beetles from the numerously very rich family of *Carabidae* are represented by about 450 species in Central Europe, most of which are useful. Of the larger species of the genus *Carabus*, the literature lists only one spe-

cies, *Carabus glabratus* PAYK. (Tab. 11, Fig. a). It occurs frequently in Central Europe mainly in broad-leaved forests. It hunts insects by night, and only during cloudy and rainy weather in the day-time. This species also

crawls into the crowns of trees since it is often observed during outbreaks of the green oak leaf roller and nun moth.

Of the larger ground beetles, *Carabus (Chrysocarabus) auronitens* FABR. has the most attractive colouring. It is up to 26 mm long; the body is green-gold and the margins of the wing cover are red-gold. It is distributed mainly in warm regions in beech forests and is always more frequent during larger outbreaks of the caterpillars of rollers and geometrids. It is exclusively a forest species. It overwinters in old stubs and beneath long stems and stones, and appears early in spring.

Sometimes its presence may not be obvious for several years, but if there is an outbreak of some harmful butterfly species, it occurs again in greater numbers in the same way as caterpillar hunters.

The ground beetles *Pterostichus oblongopunctatus* FABR. (Tab. 11, Fig. d) and *P. burmeisteri* HEER. (Tab. 11, Fig. e), which have been found many times to be important predators during the swarming of the lineate bark beetle, *Xyloterus lineatus* OL. and of other bark beetles, are much smaller. These ground beetles attack the bark beetles, remove their wing covers and shield and feed on the soft parts of their body on the spot. One specimen can consume up to 20 bark beetles daily. They occur frequently everywhere but, by day, are hidden beneath the bark of old stubs and stones, being active mainly at night.

*Calosoma sycophanta* L. (Tab. 11, Fig. b) has for a long time rightly been considered to be a useful species. During outbreaks of pests, mainly the nun moth, lasting for several years, it occurs frequently and it is well known because of its attractive and beautiful colouring. In Czechoslovakia it is protected by law. Not only the adult beetle but also the larvae are mainly active at night. The caterpillars and pupae of butterflies are consumed from the side and it seems that *C. sycophanta* L. prefers to attack the female pupae which have considerably more fatty tissues. The larvae (Tab. 11, Fig. c) pupate in the soil in ground chambers of an oval form and, during dry warm weather, very often also in the upper layers of litter. By the end of the summer, the beetles emerge from the pupae and hibernate. Some of the beetles do not survive the cruel winter. In the natural habitat, the beetles may appear by the end of May. The importance of this species was also evaluated during its introduction to America. It was successfully reared and the larvae which were bred in laboratories were successfully introduced into open grounds.

*Calosoma inquisitor* L. (Tab. 12, Fig. a) is a smaller relative of *C. sycophanta* L. It is 15 to 22 mm long, with a dark brown body (or bluish violet to blue-black in the *f. coerulea* LETZN. form, see Tab. 12, Fig. b) and the margins of the elytra are a bright brass colour. It is generally distributed over Central Europe and, in places, even occurs frequently, mainly in broad-leaved forests on hills and in greenwoods where not only the adults but also their larvae hunt caterpillars, mainly those of the green oak leaf roller, *Erannis defoliaria* CL., the winter moth *Operophtera brumata* L. and the gypsy moth. This species is also protected by law in Czechoslovakia.

# CARRION BEETLES

The carrion beetles of the family *Silphidae* (closely related to the rove beetles) feed on various decaying organic substances and are also partly carnivorous. During outbreaks of forest pests, *Xylodrepa quadripunctata* SCHREB. (Tab. 12. Figs. c—e) is an important carrion beetle. It feeds mainly on caterpillars not only on the ground but also in the crowns of forest trees. Unlike other related species of carrion beetles, it has the ability to climb trees and shrubs as does its larvae. In oak forests, it has often been found in larger numbers hunting the caterpillars of the green oak leaf roller. Although it is also frequently found on the bodies of dead mammals together with other species of carrion beetles, it prefers, during outbreaks, the green oak leaf roller caterpillars, mainly when many of them drop to the ground and are hidden in the rolled leaves of the herbaceous layer after a storm.

# ROVE BEETLES

Beetles of the family *Staphylinidae,* which is very rich in species, are strikingly slim; they have a long body with short wing covers, which in the majority of species only cover a small part of the body, and an abdomen composed of nine segments which is free from the elytra. The adults are mostly very mobile and the membranous wings under the elytra allow even the largest species to fly well. The beetles are mostly small with species characteristics which are so imperceptible that an exact identification is often very difficult. Some species are herbivorous (living on flowers), others are mainly saprophagous (living, for instance, on fungi), during the larval stage, and several species are predacious. The *Staphylinidae* family is an important component of the soil fauna in forest litter; it feeds on various organic substances, and also on moulds and fungi. We pay attention here, of course, to predacious species living under bark where the adults and larvae pursue bark beetles and their larvae. Four small species, shown in Tab. 13, belong to this group. They are: *Quedius laevigatus* GYLL. (Fig. a) and *Placusa tachyporoides* WALTL. (Fig. b) which live all year in the galleries of our most harmful bark beetle, *Ips typographus* L.; *Nudobius lentus* GRAV. (Figs. c—d) and *Metoponcus brevicornis* ER. (Fig. e) which live mainly in the galleries of *Pityokteines curvidens* GERM.

# CHECKERED BEETLES

The *Cleridae* family is represented by only a few species in Czechoslovakia, most of them varicoloured, but their life is very interesting. There are three species which are important for forest protection based on biological means. *Thanasimus formicarius* L. (Tab. 14, Figs. a—e) resembles forest ants perhaps because of the way it moves and walks. We meet this species often in the forest from spring to autumn. On warm days, it is active on the stems of live and felled trees. It is relatively shy and tries to hide itself as soon as possible. It pursues bark beetles of various species, mostly the lineate bark beetle, the spruce bark beetle, *Ips amitinus* EICHHOFF, *Ips sexdentatus* BÖRN and *Pityokteines curvidens* GERM. The larvae kill not only the larvae of the bark beetles but also their pupae and their eggs in the mother galleries. Each beetle kills daily a sufficient number of bark beetles to meet its needs mainly when they fly onto conifers. After copulation, the females deposit crescent-shaped eggs into cracks in bark near the borings of large bark beetles for several weeks, laying only a few eggs daily. Each female deposits in total about 30 eggs. The larvae emerge after a week but grow very slowly and first pupate in the autumn. During the first stages of development, the larvae feed on the eggs and emerged larvae of bark beetles and, if necessary, also on the beetles' excrement; later, the larger larvae and pupae of the bark beetles are attacked. They pupate in an oval chamber embedded with stiffened slime. The adults emerge
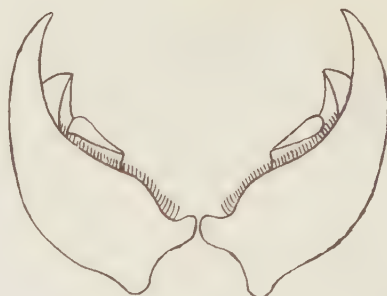


Fig. 8 Mandibles of the imago of *Pseudoclerops multillarius* FABR.

in spring. This species is considered to be an important enemy of bark beetles and has only one generation per year. With polyvoltinous species, the propagation potential is larger than with this predacious beetle.

*Pseudoclerops multillarius* FABR. is a larger species (Tab. 15, Fig. a) and a typical inhabitant of older oak forests where it pursues the adults and larvae of bark beetles, and also the larvae of various other wood-destroying insects, mainly *Bostrychus capucinus* L. The mandibles of this checkered beetle (Fig. 8) are excellently adapted for predation.

The *Cleridae* family also includes the important species, *Tillus elongatus* L. (Tab. 15. Figs. g—h) which has a striking sexual dimorphism. Its flat larvae pursue the larvae of *Ptilinus pecticornis* L.

# LESS WELL-KNOWN SPECIES OF USEFUL BEETLES

Beneath the bark of forest trees that have been attacked by bark beetles and other insect pests, the development of numerous minute beetle species occurs, the larvae of which mainly pursue the larvae and pupae of bark beetles. These species are very well adapted to life beneath bark mainly due to the flat form of the bodies of not only their larvae but also the adults and to their small size. These beetles are representatives of several families. Only recently much attention has been paid to their way of life and they may play a very important role during an outbreak of bark beetles.

Within the *Ostomidae* family, a very useful and relatively frequent species is the 5-mm long black beetle with a cylindrical body, *Nemosoma elongatum* L., which hunts some species of bark beetles. The *Nitidulidae* family also includes some very useful species. Their whitish larvae, which are strikingly similar to those of the rove beetle family, pursue the larvae of bark beetles and other bark pests. The main species is the 4-mm long

beetle with a flat body, *Epuraea laeviuscula* GYLL. (Tab. 15, Fig. d), living in the galleries of the lineate bark beetle, *Xyloterus lineatus* OL., and of *Hylurgops palliatus* GYLL.

An important predator of the larvae of the European spruce beetle, *Dendroctonus micans,* KUG. is from the *Rhizophagidae* family *Rhizophagus grandis* GYLL. (Tab. 15, Fig. b). Some representatives of the *Cucujidae* family are also of the same importance, mainly the species *Laemophloeus alternans* ER. (Tab. 15, Fig. c), which often lives in the galleries of the bark beetles, *Pityogenes chalcographus* L. and *Cryphalus piceae* RATZ. Special attention should also be paid to *Laricobius erichsoni* ROS. from the *Derodontidae* family (Tab. 15, Figs. e—f) which has hitherto been considered to be a species which seldomly occurs in forests. It is an important killer of the very harmful species, *Dreyfusia nordmannianae* ECK.

# LADYBIRD BEETLES

These small, 1 to 9-mm long, beetles of the *Coccinellidae* family have an oval-shaped body and are mostly varicoloured (Tab. 16 and 17); generally many species are known and from spring to the end of summer they occur frequently. The majority of the species are very useful since they feed on aphids and mites. These pests are consumed not only by the adults but also by the larvae, mainly those at the last instar stage of development. A higher environmental temperature shortens this stage and the ladybird larvae consume less food during warm weather. The increasing temperatures, to the contrary, cause an outbreak of aphids and so the importance of ladybird beetles is reduced.

Their metamorphosis has been very well studied. Overwintered females deposit eggs from the end of April to mid-May in small groups (of 10 to 20 eggs); in total, each female lays about 400 eggs. After five to eight days, the larvae emerge and undergo four ecdyses during their lifetime (1 to 2 months). They are mostly bluish grey with black and red-orange tubercles on the dorsum. Only the larvae of some *Scymnus* species have a layer of white wax over the body. (Fig. 9).

Not only the adults but also the larvae of ladybird beetles are equipped with sharp mandibles for grasping aphids (see Fig. 10). The pupae are firmly attached to plants and the imagines emerge after only 8 to 9 days so that from July to August some species can establish further generations (in the case of the seven spotted ladybird it is only one per year). Mating of overwintered females takes place in spring.

The two spotted ladybird beetle, *Adalia bipunctata* (L.) (Tab. 17), is interesting in that darker forms prevail in humid climates. The same phenomenon has been found in cities and industrial regions where the darker forms occur more frequently. It has even been found (TI-MOFEEFF—REESSOVSKY) that the red forms of this ladybird beetle hibernate better than the black ones. To the contrary, the dark forms are better developed in summer, are more active and thus are also more useful than the red forms. The dominant dark forms also have, as a rule, darker progeny. The development of the larvae depends not only on temperature but also on the species of food. The development of the larvae lasts four to eight weeks, and its course and the consumption of aphids by individual instars were recently carefully studied. It is no exaggeration that one larva of this most common species consumes about 350 aphids during its life time. Nevertheless, in years that are especially favourable for the development of aphids, the ladybird beetles cannot hold their populations in check. The imagines as well as the larvae seize aphids very briskly. The imagines prefer to consume wingless female aphids and disregard the more minute larvae even though they may be very nearby.

*Anatis ocellata* (L.) is our largest species (Tab. 16, Figs. a—d) at 8 to 9 mm long. It is very variable in colour and the black spots on the elytra may also be fully suppressed (Fig. 12). It is an important killer not only of aphids and scale bugs on conifers but also of the hatched larvae of *Lygaeonematus*. The banana-shaped

Fig. 9 Larva of *Scymnus*

*Fig. 10. Mandibles of adults and larvae of some species of ladybird beetles. From top to bottom left: adult Adalia bipunctata L., adult Chilocorus bipustulatus L. and larva of this species. Right: mandibles of Exochomus larva, of Scymnus frontalis FABR. and of adult Coccinella septempunctata L.*
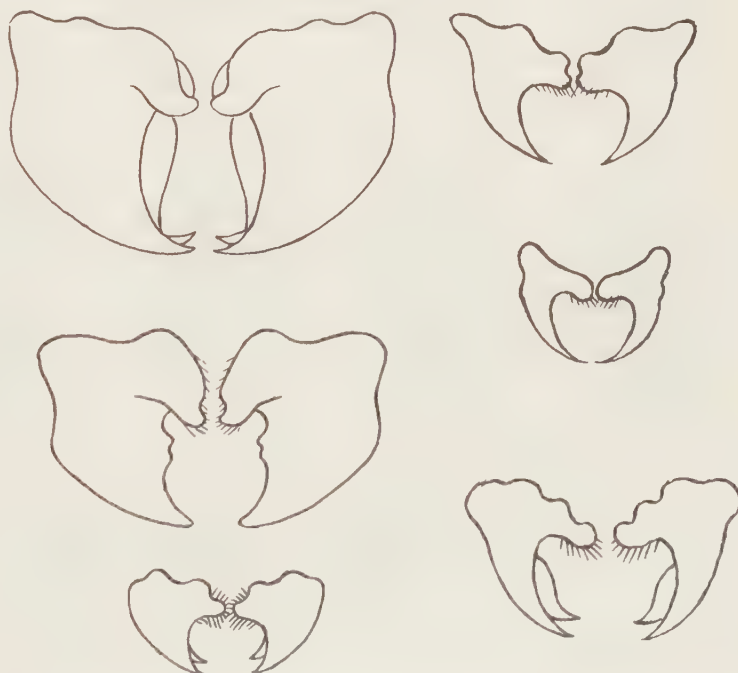
eggs are deposited individually on needles. The larvae are very mobile and voracious; one can consume up to 2000 eggs and larvae of *Dreyfusia nordmannianae* ECK. per month. The adults sometimes also consume the hatched caterpillars of the nun moth. *Coccinella septempunctata* (L.) the seven spotted ladybird, has little variation in colour (Tab. 16, Figs. e—h) and is distributed over the whole palaearctic region including India. The lemon-yellow eggs (Fig. f) are always laid in small groups. The larvae (Fig. g) and pupae (Fig. h) are in general well known. The larvae are very voracious and consume aphids (over 300 during their lifetime), scale bugs and butterfly eggs and, when necessary, also the larvae and eggs of their own species. The somewhat smaller species *C. quinquepunctata* L. occurs less frequently but has the same way of life.

The two spotted ladybird beetle. *Adalia bipunctata* L. is the most frequent species found in Central Europe. It is a typical predator of a wide variety of aphids and for this reason is a very important species (Tab. 17, Figs. a—f). During wet and cold years, the dark forms (Figs. b—c) occur much more frequently than the red ones

and the progeny of the dark forms are also mostly dark. In former times, some tens of different varieties have been described but today these have not been confirmed. The larvae are similar to those of *Coccinella septempunctata* L. but are smaller (Figs. d—e).

*Adalia conglomerata* (L.) (Tab. 17, Fig. g) is a mountainous species. It is mainly distributed over the foothill regions of the Alps; in Czechoslovakia, it occurs here and there. It is an important predator of aphids on Douglas fir.

The genus *Scymnus* includes 28 small Central European species which are difficult to identify. We present the four most common species found in forests in Tab. 17 (Figs. h—k). The varieties of some species are considerable.

*Chilocorus bipustulatus* (L.) (Fig. l) is striking with its hemispheric convex body and cannot be confused with other species. Similar in size to it are two further species, *Ch. renipustulatus* (SCRIBA.) (Fig. m) and *Exochomus quadripustulatus* (L.) (Figs. n—p). The adults and larvae of these species are important predators of scale bugs and for this reason are very beneficial.
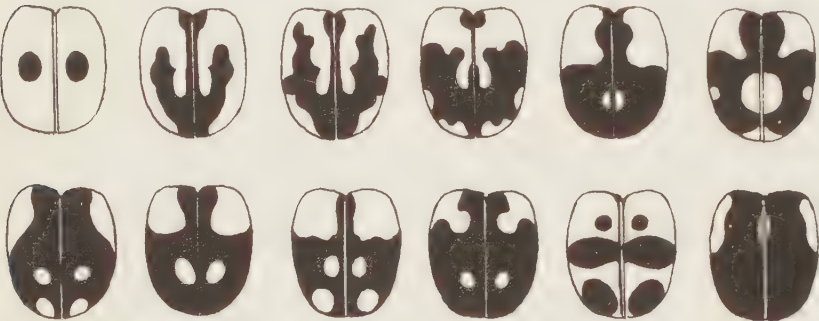
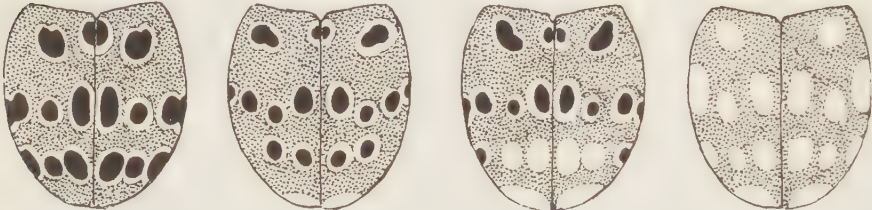Fig. 11 Variability of the markings of *Adalia bipunctata* (L.)

Fig. 12 Variability of the markings of *Anatis ocellata* (L.)

Fig. 13 Variability of the markings of *Scymnus frontalis* (F.)

Fig. 14 Variability of the markings of *Propylaea quatuordecimpunctata* L.

*Propylaea quatuordecimpunctata* (L.) (Figs. r—t) is the most widely distributed species and also the most varied in colour. It sometimes exceeds the two spotted ladybird beetle in its predation of a wide variety of aphids and the consumption of vegetation by some generations.

*Hyperaspis campestris* L. (Fig. u) is, to the contrary, a less frequent species. It lives on the borders of broad-leaved forests and pursues scale bugs.

*Coccinula quatuordecimpustulata* L. (Fig. v) occurs, as a rule, very frequently on the borders of forests and in nearby meadows during summer.

# SNAKE-FLIES

Snake-flies belong to the ancient insect order *Raphidioptera* and are of average body size. The wing span of these insects which do not occur frequently in forests is 14 to 31 mm (Tab. 18 Figs. a—e).

The typical body structure has the characteristic extended prothorax. The head is dorsoventrally flattened and prognathous, with biting mouthparts. The head has two compound eyes and the majority of species have three ocelli. The antennae are relatively short and moniliform. There are two pairs of glassy transparent wings which fold roof-like over the abdomen and which have nearly identical brown venation. On the front border of both pairs of wings, there are coloured pterostigma, frequently with one or two transverse veins. The legs are ambulatory. The abdomen is relatively long and, in males, has the exterior genitalia and the typical morphology at the end, while females have a quite long ovipositor (Fig. a). The body is dark brown and relatively strongly sclerotized, with white to yellow markings. Nine species of snake-flies have been found in Czechoslovakia. The eggs are oval, white or yellowish (Fig. e) and tapered towards the back. The larvae (Fig. c) have a slightly extended protohorax, are dorsoventrally flattened, with robust mandibles (Fig. d), and are brown to dark brown coloured, with white to yellowish markings. The pupae are free and enclosed in an oval chamber.

The adult insect is only seldom found in large quantities on shrubs and tree stems from April to August. All of the species are predacious, not only the larvae but also the adults, and they consume small insects. The larvae of most of the species live under tree bark and some of them in forest litter. Those living beneath bark are of considerable importance for the natural regulation of the population density of bark beetle larvae. They mainly feed on these and pursue them in their galleries where they move swiftly both forwards and backwards. Their development takes about two years; the larva and prepupa hibernate and the imagines emerge in spring. Snake-flies occur in forests (usually on their borders), on clear cut areas, and in gardens and orchards, mainly in warmer and drier spots. The larvae are sometimes found in large numbers.

The most frequent species found over the whole of Europe is *Raphidia flavipes* STEIN. Its larvae live in forest litter. A typical species found under bark in coniferous forests is *R. notata* F. This is one of the largest species. Its larvae feed on the larvae of bark beetles. The literature often mentions the snake-fly *R. ophiopsis* L. but this species is much rarer. The larvae live beneath the bark of trees, in forests, parks and orchards. The earliest species found in spring, by April, is *R. xanthostigma* SCHUMMEL which currently occurs in broad-leaved, beech and beech/oak forests.

# NEUROPTERA

*Neuroptera* is an ancient order with several families which are not too rich in species and have a perfect metamorphosis. In Central Europe, there are representatives of eight families which obviously differ in their morphology and some also in the lifestyle of the larvae. The larvae of all of the species live predaciously as do the imagines of the majority of species. There are representatives of three of the richest families in terms of species, *Coniopterygidae, Hemerobiidae* and the best known group *Chrysopidae,* which are the important natural bioregulators of the population density of sucking insects, mainly of aphids and other small species. Besides these, we may only find the ant-lion in pine forests although its larvae are better known since these often occur on the sandy borders of forests in large quantities. However, they are not interested in phytophagous forest pests because their main food is ants.

*Coniopterygidae* (Tab. 18. Figs. h—j) is a little known group, although it is abundant in forests. Due to its representatives' small size, wing span (only 5 to 9 mm) and low activity, it is recommended that attention is drawn to them. The body and wings of all of the living species in Central Europe are dusted with wax secretions, so that they strikingly resemble white-flies. The head is orthognathous with biting mouthparts and relatively short moniliform antennae. On the thorax, there are two pairs of wings with the same venation which is of an ancient type: simple, little branched and with only a few transverse veins. Sometimes the hindwings and venation are reduced (for instance, in *Conwentzia* species).

The wax cover over the body can be rapidly dissolved by immersion in alcohol and the venation of the wings can be more clearly seen. Fifteen species have been found in Central Europe. The eggs (Tab. 18, Fig. i) are oval and are deposited individually on the lower side of leaves or on needles. The larvae (Tab. 18, Fig. j) are broadest in the centre of the body. Their head has a large broadened last segment of the labial palpi. The legs are relatively long and ambulatory. The body often
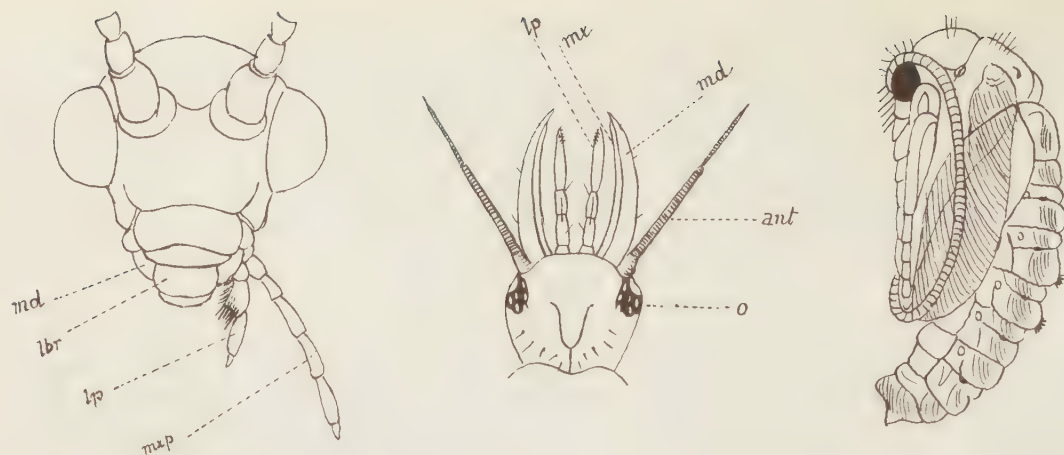
Fig. 15 — Frontal view of the head of imago of *Wesmaelius quadrifasciatus* REUT.

Fig. 16 Head of the larva of *Westmaelius quadrifasciatus* (Reut.) from above: lbr. — upper labrum, md — mandibles, mx — maxilla, mxp — palpi maxillares, lp — palpi labiales, ant — antennae, o — ocelli

Fig. 17 Side view of the pupa of *Wesmaelius quadrifasciatus* (Reut.)

has characteristic dark markings on a whitish background colour. They live mainly on the lower side of leaves. The pupa is free in the flattened cocoon. Some species have one and others two generations each year. The cocooned prepupae hibernate. The imagines and larvae are predacious and live on minute phytophagous insects and their eggs, or even on small acarids (tetranychids) and their eggs. They are important natural enemies and regulators of the population density of small sucking insects and acarids. During their development, the larvae consume 120 to 150 recently born aphids or acarids. Our most common species, *Coniopteryx parthenia* (NAVAS et MARCET) = *C. pygmaea* ENDERLEIN live in coniferous forests. An outbreak of phytophagous insects often occurs on Scots pine, larch and silver fir from oak forest to Norway spruce forest. In these same biotopes, one of our largest species, *Conwentzia pineticola* ENDERLEIN, which has its hind wings considerably reduced, also appears. *Aleuropteryx loewi* KLAPÁLEK only occurs on Scots pine and *Heliconis lutea* (WALLENGREN) only on spruce. Some of these species live in broadleaved forests; the most common is *Semidalis aleyrodiformis* (STEPHENS) (Tab. 18. Fig. h).

Two generations of imagines of this species develop in large quantities on summer oak, hawthorn, hazel-nut, hornbeam, pear and other broad-leaved trees in oak to oak/beech forests from May to September. This species, due to its frequent occurrence, is of special importance for the regulation of small pytophagous insects. *Conwentzia psociformis* (CURT.) a species with reduced hind wings, is frequently found mainly on summer oak.

The hemerobiids or brown lacewings (*Hemerobiidae*, see Tab. 19) are morphologically the most varied group of the aphidophagous Neuroptera and, in Europe, the richest group in terms of species. Their wing span is from 5 to 15 mm. Thirty six groups have been found in Central Europe. Their head is orthognathous (Fig. 15), with biting mouthparts and quite short moniliform antennae. There are two pairs of wings on the thorax, the second pair of which is sometimes stunted. The wings

are yellowish, brown or grey with dark spots or bands and with hairy veins. In some exceptional cases, the wings may be transparent with black spots. When folded, the wings form a roof over the abdomen. The eggs are oval, white or yellowish, 1 mm long, and are deposited individually on the leaves of trees and shrubs, most often near the veins of the leaves. The larvae have an oblong body, which is broadest in the centre. The mandibles (Tab. 19) are elongated, and close to the jaws which together form a groove connected to the mouth. They are used for easy grasping and sucking of the prey. The body of the larvae is sparsely covered with hairs. The larvae do not attach the remains of their prey to their dorsal side as has often been described in the literature. They often pupate in slightly oval cocoons directly on plants or in litter. The pupa is free. The imagines are active mainly in the evening and at night. When disturbed, they pretend to be dead. The imagines and larvae live on minute phytophagous insects, mostly aphids and scale bugs, and consume 100 to 200 specimens during their development. There are usually two generations each year. Due to the number of species and the frequency of their occurrence, they are important regulators of the populations of small sucking insects.

Some typical *Hemerobiidae* species live on coniferous trees and in forests. The most common and widely distributed species is *Hemerobius pini* STEPH. (Tab. 19, Figs. g—h). The adults and larvae occur on all coniferous trees from April to September from oak to mountain pine forests, as a rule only up to 2000 m above sea level. A larger species is *Wesmaelius quadrifasciatus* (REUT.) (Tab. 19. Figs. a—b, and Figs 15—17), which has broad wings. Its size is very varied. The imagines occur from May to August. This species prefers larch and spruce at elevations between 200 and 800 m above sea level and the highest they are found is in foothills. *H. atrifrons* McLACHLAN. (Tab. 19, Figs. e—f) occurs from May to September in two generations on larch, mainly in younger stands at 200 to 900 m above sea level. All year round, in coniferous forests, rusty brown coloured *H. stigma* STEPH., whose adults hibernate, occurs.

*H. nitidulus* lives only on pine trees. This species is dark brown coloured with brown wing membrane and dark spots on the veins. It flies from April to September.

*W. concinnus* (STEPH.) is a larger species with a wing span from 18 to 25 mm; it is brown-coloured and typical in pine stands. Finally, in warm to xerothermal pine

stands, a smaller species, *Sympherobius fuscescens* (WAL-LENGREN), with a wing span from 10 to 12 mm and dark smoky coloured wings may frequently occur.

The most frequent and most widely distributed species in broad-leaved forests is *H. humulinus* L. (Tab. 19, Figs. i—j). It is a species adapted to the widest variety of biotopes occurring in oak to oak/beech forests at elevations from 200 to 1000 m above sea level. Another common species in broad-leaved forests is *H. micans* OLIV. (Figs. c—d). Imagines of this species fly from April to October at elevations between 200 and 800 m above sea level. This species prefers beech forests where is the dominant species there, often being the only one present. Due to its wide distribution, *H. micans* OLIV. is one of the important regulators of the population density of *Phyllaphis fagi* (L.)

*Drepanopteryx phalaenoides* (L.) (Tab. 18, Figs. f—g) lives mostly in broad-leaved forests where it is bound more to the shrub undergrowth. It has also been found in a massive quantity in silver fir forests. The imagines live from April to September. The typical species in oak and maple forests is *H. lutescens* F. In the foothills of mountains with more humid climates, the typical species is *H. marginatus* STEPH. On broad-leaved trees and shrubs, the common species are the dark gry *Wesmaelius nervosus* (F.) and *W. subnebulosus* (STEPH.), their larvae live in the galls of aphids.

The green lacewings of the *Chrysopidae* family (Tab. 20) are the most interesting group of the order Neuroptera thanks to the most common and the most frequently occurring species, *Chrysoperla carnea* (STEPH.) (Tab. 20, Figs. c—f), which hibernates in human residences. Green lacewings deposit eggs on stalks (Fig. 18) about 10 mm long, which were originally described as independent species of fungi. The imagines are of mean size, mostly green coloured (with the exception of some red-brown specimens) with a wing span of 18 to 48 mm. The head is orthognathous, with biting mouthparts and
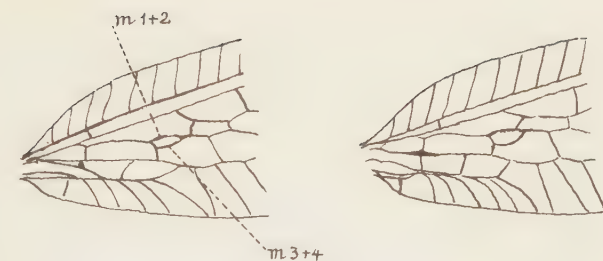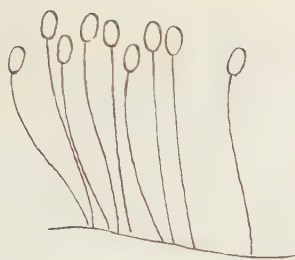
Fig. 18 Eggs of *Chrysopa septempunctata* WESM.

Fig. 19 Base of the wing of *Chrysoperla carnea* (STEPH.)

Fig. 20 Base of the wing of *Chrysopa septempunctata* WESM.

symmetric or asymmetric mandibles. The antennae are long and thread-like. The eyes are very striking, opalescent and gold. The wings are relatively long and wide, with the same venation on both pairs, and fold roof-like over the abdomen. Twenty five species have been found in Central Europe. The larvae have long, sickle-shaped mandibles and jaws close together which form a sucking tube similar to that of *Hemerobiidae* larvae. Chrysopids mainly suck the juices of aphids, requiring from 100 to 300 for their development. There are papillae and always various chaetae on the larval body of some species. In some species, these chaetae are bent and adapted for grasping the remains of their victims or parts of plants which the larvae use to cover themselves to become inconspicuous (Tab. 20, Fig. j). It is mainly the webbed prepupae which hibernate although the imagines of some species may also do so. The pupa is free in an almost spherical cocoon (Tab. 20, Fig. f). The green lacewings constitute, due to the number of individuals, one of the most important bioregulators of the population density of aphids in forests.

The precise identification of *Chrysopidae* species is sometimes very difficult because the most important specific characteristics are not only the venation of the wings (Figs. 19—20) but also the colour of the body, particularly that of the thorax, as is shown in Figs.

Fig. 21 Head and prothorax of *Chrysopa dorsalis* BURM.

Fig. 22 Head and prothorax of *Chrysopa perla* L.

Fig. 23 Head and prothorax of *Chrysopa septempunctata* WESM.

Fig. 24 Head and prothorax of *Anisochrysa*

21—24 (the head and prothorax of *Ch. dorsalis* BURM.), 22 (*Ch. perla* L.), 23 (*Ch. septempunctata* WESM.) and 24 (*A. prasina* BURM.) respectively *Ch. carnea* STEPH. larvae can be easily reared on artificial food and then liberated on plants attacked by aphids, harmful butterflies or the larvae of beetles. The polyphagous larvae are able to destroy the above-mentioned pests without the need for insecticides. Experiments are also being carried out on the mass rearing of other species of *Chrysopidae*.

One of our largest species, *Nineta pallida* (SCHNEIDER) (Tab. 20, Fig. b), lives in coniferous forests. It is typical of the spruce stands of lowlands and mountains up to an evelation of 1 000 m above sea level. The imagines occur from July to September. The larvae hatch in autumn and hibernate. The development to pupation ends in the spring. *Ch. dorsalis* BURM. (Tab. 29, Fig. g, and Fig. 21) is a species typical of pine forests, mainly in xerothermal regions on loose sands and in forest steppes. It may be found on Scots pine from 180 to 600 m above sea level. Our smallest species, *Tjederina gracilis* (SCHNEIDER), has narrower opalescent wings and a darker body colour. It prefers spruce forests at elevations from 190 to 800 m above sea level. The imagines hibernate.

The most common species found mainly on the borders of broad-leaved forests is *Ch. carnea* (STEPH.) (Tab. 20, Figs. c—d). The imagines of this species are found all year round with the exception of a short period in June when the larvae of the second generation appear. This species occurs up to an elevation of 1 650 m above sea level. *Ch. perla* (L.) (Tab. 20, Fig. h), is the second most well-known species. It is very often confused with the above-mentioned species although it differs not only in its colouring but also in its markings and life cycle. The imagines and larvae live on trees and shrubs in coniferous and broad-leaved forests. They fly onto the undergrowth of raspberries and are also frequently found on clear cut areas. This species has part of the second generation occurring each year from June to September at elevations from 110 to 1 100 m above sea level.

*Ch. septempunctata* WESM. (Tab. 20, Fig. a) deposits its eggs in larger groups on the leaves of shrubs and trees. It is common in broad-leaved forests and also in town parks. Like other species, *Ch. septempunctata* WESM. is attracted by fluorescent lights and so many individuals die in the protective cover of street lamps.

*A. prasina* (BURM.) (Tab. 20, Figs. i—j), is common in broad-leaved forests, mainly in oak stands. The imagines stay in tree crowns. The larvae hibernate in forest litter and afterwards climb into the tree crowns, where they may be found in spring in considerable numbers, and also on sticky bands on oak stems. *A. prasina* (BURM.) is one of the species whose larvae cover the dorsal side of their body with the remains of plants and their aphid prey (Tab. 20, Fig. j). In broad-leaved forests, there also live other species of *Chrysopidae* like *Nineta flava* (SCOPOLI), which is typical in maples at higher elevations. *Chrysotropia ciliata* (WESM.) is common in submountainous, more humid forests of beech—oak and oak—beech stands. The larva of this species is adapted for attaching the remains of its prey and fragments of plants to the dorsal side of its body.

# ROBBER—FLIES

Robber-flies are striking large flies (from the *Asilidae* family) with a long slender body, and the largest species also have dense rough hairs. All of the species have a very mobile head, which is strikingly large, stary eyes with a wide visual field and stiff mouth labellae, which allow them to seize more difficult prey (larger weevils) firmly. The cylindrical or slightly flattened larvae live beneath the bark of stubs in the wood of dying trees.

The most striking and largest of our species is *Laphria flava* L. (Tab. 21, Figs. a—c). Robber-flies settle on selected places, usually on stubs and logs, and often return after hunting. They attack insects in flight and carry their prey to a quiet place and feed on them by sucking their juices. Robber-flies do not occur frequently in forests. Most often they are found on stubs in clear cut areas (Fig. d). Robber-flies are not of great importance in the overall areas of forest protection because they hunt all flying insects, including bees, but they are interesting predacious insects in that they are almost unique among the Diptera. The striking yellow colour of the abdomen is also found in *Asilus crabroniformis* L. A somewhat smaller and slender species is *Pamponerus germanicus* LW., which is dark coloured. Its larvae destroy the larvae of bark beetles.

# LONCHAEIDS

These are small flies from the *Lonchaeidae* family which are striking in their stiff ovipositor and life cycle. The larvae of some of the species are saprophagous, living in decaying plant materials, beneath dead bark and, some species, in manure; only the larvae of some species are carnivorous. Prior to copulation, the adults live on flowers. Our interest is concentrated on one species, *Lonchaea seitneri* HENDEL (Tab. 21, Figs. e—h). It is a minute blue fly with a bright metallic lustre on the thorax. The abdomen of the female ends in a stiff articulated ovipositor which deposits eggs into the mother galleries of bark beetles. Its larvae suck on the larvae and pupae of the bark beetles and pupate in their cradles. The emerging adults get out through the borings made by the bark beetles. Although this species does not occur frequently in forests, it can considerably affect the populations of bark beetles since the number of eggs laid by a female is large.

# FLOWER-FLIES

*Syrphidae* is an important species-rich family of the *Brachycera* suborder (Tab. 22 and 23). Due to numerous typical characteristics, *Syrphidae* species are easily differentiated from other *Diptera* (by their wing venation). The abdomen of the majority of species is decorated with striking yellow half-moon-shaped spots. The eyes are large, naked or finely haired, and closely tapered on the top of the males' head; many species have upper facets which are larger than those on the lower part of the eye. Ocelli always present, the third segment of antennae bristled. Like other good insect fliers, they have a well-developed thorax, mainly the mesothorax. The scutellum is of a half-circular form and underneath it is the valuted part, the so-called plumula. The legs have short hairs. The abdomen has nine segments. The females have a considerably broader abdomen than the males or it is strikingly shorter and the end is different. The whole periphery of the body is covered in fine hairs which assists hovering and swift flight. There are about 300 species of this family in Central Europe. Some of them have a high frequency. Attention is given here only to aphidophagous species since their larvae consume only aphids. *Syrphidae* species are important population regulators during mass outbreaks of numerous species of aphids on a wide variety of plants. In this respect, they are often of greater importance in the natural habitat than the larvae of ladybird beetles and parasitic Hymenoptera. The larvae of the species *Xanthandrus comtus* (HARRIS) even suck on the caterpillars of the oak tortricids, the larvae of *Dasysyrphus tricinctus* FALL. (Tab. 22) and the larvae of the saw-fly, *Pachynematus scutellatus* HTG.

Aphidophagous species of *Syrphidae* have larvae of a typical spindle shape, which are amphipneustic and often variously coloured (green, yellow, white and orange-spotted) with translucent skin. Using the naked eye it is possible to see the jerky movements of the branched arms of the air tubes and the whitish clod-like formations of the fat tissues (Tab. 22). The hind stigmata are on very short carriers and very close to each other. The larvae are blind. The number of their body segments is seemingly large since the segments are divided transversely. Movement is permitted by tubercular protrusions on the ventral side of the body and also often short branched hairs. The movement is similar to that of leeches and also enables the larvae to have a firm grasp on the surface they are moving over. The larvae pupate in the skin of the last instar (puparium). The puparium is much shorter than the full-grown larva and is tear-shaped with a pair of hind stigmata on the narrowest end. It is attached by these stigmata to the ground. When the imagines emerge, the puparium is different to that of other representatives of *Cyclorapha* in that it is open only on the dorsal side (Fig. f); this is quite typical of these species and the empty exuvium remains for a long time in its original place. Depending on the weather, the imagines emerge within about three weeks. The blind larvae use the typical method in the search for their food (aphids). They make swinging movements with the highly mobile front end, and cling firmly to the ground with the last segments of the body. The mouthparts have sharp hooks and, above these, a pair of protrusions considered to be reduced antennae. The mouth hooks are dagger-like and directed forward; they may be drawn rapidly into the body and so serve excellently for the rapid capture of aphids. The larva grasps the aphid, jerks it towards its mouth, sucks the contents of its body and casts the remains away. This process is relatively rapid.

Aphidophagous species belong to the following genera: *Didea, Paragus, Melanostoma, Platycheirus, Episyrphus, Megasyrphus, Eriozona, Dasysyrphus, Metasyrphus, Syrphus, Epistrophe, Sphaerosphoria* and others. These genera are mainly from the subfamily *Syrphinae*. In addition, from the subfamily *Pipizinae*, aphidophagous species belong to the genera *Heringia, Pipizella* and *Pipiza*. The larvae of these three genera feed mostly on the gall aphids *Dreyfusia* and *Pemphigus*. Most of imagines of the species of the subfamily *Syrphinae* fly very swiftly and can hover. The imago rests for some moments on one spot; it can move very rapidly to another place and then return quickly. This makes it possible for them to find not only hidden colonies of aphids but also individual aphids while flying. Their eggs are deposited individually, rapidly and very often during flight. The extremely swift movements of flying syrphids (libellilids fly in a similar way) during quiet and sunny weather hinders the birds, libellilids and robber-flies trying to catch them. It may often be observed that neither flycatchers, wagtails, redstarts nor singing birds which can capture *Diptera* so easily in flight are ever successful in catching syrphids. However, many syrphids are the victims of spiders' webs, mainly on forest borders.

Syrphids occur frequently over the summer period until autumn. During flight, they make a typical noise which is audible from the crowns of coniferous trees in forests during quiet weather and which is strengthened by the noise of wasps. Hitherto, little has been known about the nutrition of mature syrphids. They often consume pollen which has been moistened by dew or nectar for the protein content which is necessary for maturation of their egg stock. They lick the limed hairs of mullein flowers and also sit for a long time on flowers sucking the sweet sap. They probably also suck honey dew and the sap of wounded plant tissues. Moistened pollen is collected from the surface of mature pistils. It is not true that they penetrate into closed pistils as is often cited in the literature.

Most syrphid species have a few generations each year. The imagines are most numerous during the second part of August; at that time they are the most frequent species of insects found on flowering plants, mainly Umbelliferae. Only warm days without wind are favourable for them. On these days, they fly from the early morning hours onto vegetation and search for dew and for open nectaries. The puparia and also the imagines hibernate. In the wild, the larval period of syrphids does not fall within the period of the maximal development of aphids, i.e., from the end of May to the

end of July. For this reason the larvae of syrphids cannot consume the rapidly developing populations of aphids in the necessary quantities in the way that ladybird beetles can.

We have sometimes observed that, at the end of summer when aphids and other insects are reduced in number, syrphids search for retarded aphid colonies and, as a rule, destroy them. Phenologically, this is the period at the end of both the flowering of chicory and the occurrence of the solitary bee, *Dasypoda altercator* HARR.

One of the most frequent species of *Syrphidae* is *Scaeva pyrastri* L. (Tab. 22, Figs. a—f). It is 14 mm long and, from spring to the end of summer, it occurs frequently everywhere. The larvae are variously coloured according to the species of aphids which they consume but are most often yellow-green. Of similar frequency during the warm summer months is *Epistrophe balteata* DEG., which has an ochre brown abdomen with transverse black stripes (Tab. 22, Figs. g—j). The larvae pursue aphids of a wide variety of species not only on broad-leaved trees but also on shrubs and herbs. An associated species is *Dasysyrphus tricinctus* FALL. (Tab. 22,

Fig. k). Its larvae also destroy the emerged larvae of the spruce webworm *Cephaleia abietis* L., *Syrphus ribesii* L. (Tab. 23, Figs. a—b), *Megasyrphus annulipes* ZETT. (Tab. 23, Fig. c) and *Posthosyrphus luniger* MEIG.

Sexual dimorphism is considerably pronounced in *Sphaerosphoria scripta* L. (Tab. 23, Figs. j—l). Relatively few species of Syrphidae have an abdomen which is without a striking colour or little pronounced yellow spots or which is completely grey-black as in *Melanostoma mellinum* L. (Tab. 23, Figs. f—h). The minute species *Heringia virens* F. (Tab. 23, Fig. i) is important because its larvae suck the juices of root aphids. For this reason, the female deposits her eggs on a soil surface. The species is relatively common but does not occur frequently anywhere.

In the adult form, syrphids, like other species of *Diptera*, are very sensitive to all kind of pesticides and die very soon after pesticide treatments. Thus, the large-scale use of pesticides can destroy the syrphid population and the consequence of this may be a striking increase in the number of aphids possibly for several years.

# PARASITOIDS
# HYMENOPTERA

*Hymenoptera* is divided into three suborders. The first, *Symphyta*, includes the known herbaceous wasps and saw-flies. Their females have a saw-like ovipositor and the abdomen is near to the thorax. In Central Europe, their species composition is rich. The larvae feed on leaves or live in wood. They are important pests, mainly of conifers.

In the second suborder, *Terebrantia*, the females have a smooth ovipositor of varied length, filiform or moniliform antennae and the abdomen is attached to the thorax by a stalk. The larvae are legless, live parasitically on other species of insects, and those of only a small number of species develop in galls and in seeds.

In the third suborder, *Aculeata*, the females have a modified ovipositor (terebra); the wings are either developed, missing or present only at swarming time

(ants). The abdomen is attached to the metathorax by a stalk. The larvae are legless. Ants have been discussed in the section on predators in the early part of this publication. Other representatives of this suborder are of no importance in the biological control of pests.

The following four sections discuss representatives of the second suborder, ichneumons, braconids, chalcidflies and aphidiids, but only the species which are most important for Central European forest pests control. Their importance is obvious because all of these species have, from ancient times, taken part in maintaining the balance of insect populations and cannot be replaced. Only a few species have names in languages other than in Latin. These species are illustrated here in colour for the first time in a book produced in Central Europe.

# ICHNEUMON-FLIES

*Ichneumonidae* (Tab. 24—33), is the richest family in the insect class in terms of species. There are more than 21 000 species of ichneumonids in the world. In Central Europe nearly 2 000 species have been found but this number is not definitive. These species belong to 26 subfamilies, the taxonomy of which is still little understood. This is mainly because the ichneumonids are mostly minute insects, unstrikingly coloured, and often have different characteristics for the two sexes. Hitherto, we have not known the hosts of many of the species and this is of importance in practice.

The system of veins on the wings and the valuted abdominal tergite are characteristic for the ichneumon-

flies. They differ from the closely related family of braconids which is also numerous in species, in their second recurrent vein in the forewing and their uncoalesced second and third abdominal tergites. There are many main differences between the subfamilies (the form of the clypeus and carinae on the hind margin of the mesothoracic sternite; the areola in the forewing which is either open or closed; the abdomen and the structure of its first tergite; the apical sternite; the type of ovipositor; etc.). Some of these are quite specific for the individual subfamily (e.g., the form of the claws on the tarsi, the type of mandibles, etc.). Over the whole world, there are very few experts on this insect.

The genera and species of ichneumonids were for a long time classified according to differences in body colouring; however, because many species vary considerably in colour, this led to the mistaken description of new species. Eventually, the use of morphological characteristics of various parts of the body and different microscopic details of the genitalia resulted in the taxonomy of the genera and species finally being based on solid principles, as is common with other insect groups today, particularly small butterflies and beetles. Apart from this, ichneumonids of the subfamily Tryphoninae have important differences which include the form of the eggs and the way in which they hang from the ovipositor. It is probable that the future will bring other means of differentiation and that electron microscopy will be applied so that the determination of the species may be perfected.

The majority of ichneumonids are winged. The females of some genera have short wings (e.g., *Theroscopus*) or are wingless (e.g., *Gelis*, see Tab. 32. Fig. c). Wingless males are rare. Females of all of the ichneumonids species have an ovipositor which is either short, hidden in the last ventral segments so that it is not visible from above, or it varies in length and in some species may exceed twice the length of the body. The size of the body varies considerably according to species. The tiniest species are only about 2 mm long (*Tersilochus* and *Stictopisthus*) and the largest species (*Rhyssa*, see Tab. 24, Figs. a—d) are, excluding the ovipositor, up to 5 cm long. Scientists have also tried to become acquainted with the development stages of the individual species of ichneumonids, which requires effective knowledge not only of their hosts but also of their whole way of life. For this reason, descriptions of the larvae of ichneumonids have related to only the last developmental stages and have hitherto been used solely for the determination of the genera. Up until now, few studies have considered the morphology of the eggs, even though this is a very interesting subject and, in many of its respects, these insects are unique.

All species of ichneumonids are parasitoids, attacking the larvae and pupae of other insect species. They never attack adult insects (imagines) and not parasitize insects with an imperfect metamorphosis, for instance, bugs. Only a few species develop in spider egg sacs or as exoparasites of spiders, and one species (*Obisiphaga*) even parasitizes the eggs of *Obisium*. Ichneumonids are not known to parasitize eggs; although females of the genus *Ctenopelma* deposit eggs inside other insect eggs, the ichneumonid larvae develop first in the larvae and then the pupae of the host. The majority of ichneumonids parasitize caterpillars and the pupae of butterflies. Representatives of one family parasitize the larvae of saw-flies. Several species also parasitize the larvae and pupae of beetles, and *Diptera*.

A considerable number of ichneumonids have a broad spectrum of hosts. They parasitize, for instance, many species of butterflies. Others have, to the contrary, a very narrow spectrum of hosts or are specific for only one species of host. The reasons behind this variability in the selection of host are connected with physiological and ecological influences. Of most importance are the ecological factors since each species has a specific distribution for the adult form. This specific distribution and the orientation scheme used in the search for the host determine the variability of the complex of hosts. It should not be taken for granted that the occurrence of polyphagous species of ichneumonids is the result of the presence of a certain species of host and its number (for instance, at the outbreak of a pest); it is an ecologically advantageous biotope, which is important. A narrower spectrum of hosts is for this reason very often a consequence of their presence in a suitable biotope or the distance of their random flight. Ichneumonids do not attack some insect species only because these live in biotopes which are unsuitable for ichneumonids. An important aetiological factor which influences the host complex of ichneumonids is the orientation ability of the females during the search for a host. She looks for the host using smell, touch and sight. The functions of the senses complement each other in the majority of cases. An important element in the search for a host is the orientation scheme, which is specific for individual species (or related groups of ichneumonids), and for the depositing female this starts with the attractiveness of certain plants or their parts. This attractiveness of plants is, for individual species of ichneumonids, so great that parasitoids of the pests of conifers seldom parasitize the same or the related species of pests on broad-leaved trees and vice versa. Also the type of plant or substrate selected for deposition is specific for individual species of ichneumonids. For example, eggs may be deposited into shoots attacked by pests, beneath bark, into the wood of stems, into rolled leaves, into the buds of terminal shoots, into dead wood, in a host in forest litter or on the soil surface in the forest; each of these is always a feature of only a certain group of ichneumonids.

The physiological influences on the selection of the host are the result of the adaptability of ichneumonids to the odours of plants or the hosts or of the ability of the eggs, or possibly of the larva, to survive in the body of the host. Some hosts are able to encapsulate and kill the deposited ichneumonid egg or the already hatched larva. It was found that these defensive reactions are effected by amoebocytes, which are a component of the haemolyph of the host. Phagocytosis kills the embryo in the egg or the ichneumonid larvae soon after hatching. Encapsulation is obvious in unsuitable hosts. However, it is known that the encapsulation ability of a host varies according to ecological conditions. The often very complicated ecological-physiological relationships of ichneumonids complicate the economic evaluation of their effectiveness and usefulness, and detailed studies of the aetiology of these species are required before they can be used in the biological control of pests.

The occurrence of ichneumonid adults in selected biotopes is dependent on the availability of water either from dew or rain. This main requirement for the environment is a further decisive factor which determines host relationships and the effectiveness of ichneumonids as parasitoids of forest pests. For this reason, ichneumonids occur in moist and protected regions with a high precipitation. The large water consumption of ichneumonids is due to the high rate of evaporation of water from the body surface of these swift mobile insects. Parasitism generally does not supply the necessary water in the food as is the case with phytophagous species. For this reason, females of some ichneumonids complete their water requirement by piercing the larvae or pupae of the hosts with their ovipositor and consuming the body sap which not only supplies the necessary

quantity of water but also accelerates the maturation of the eggs in the ovaries. It was observed in ichneumonids of the genus *Pimpla* that males also search for wounded host larvae and pupae as sources of water and food. The high demands of ichneumonids for moisture are the reason for their regular occurrence in shaded forest biotopes and in moist meadows. The suitability of the forest biotope for ichneumonids is increased when there is a reduction in air flow, perhaps due to calm weather or a change in sun exposure. The high demands of ichneumonids for moisture are also apparent in their greater activity at night and during the morning.

An important property of ichneumonids is their considerable mobility and adaptive dispersion connected with their ability to change or alternate biotopes rapidly, according to their ecological suitability by flying. So some species of ichneumonids, for instance of the genera *Phygadeuon* and *Diplazon*, fly over long distances. However, even in suitable biotopes, ichneumonids occur in small numbers and often only individually. Larger groups of ichneumonids in isolated spaces, for instance, on stands of the flowering plants of *Daucaceae*, are only their preliminary refuge during dispersion. In some biotopes, ichneumonids occur frequently only at the time when their adults emerge or when suitable conditions for egg laying are available, for instance, in suitable biotopes where there is a mass outbreak of a forest pest, their host.

In Central Europe, there have hitherto been more than 250 species of ichneumonids reared from forest pests. The present publication lists only 40 of these, i.e., one sixth, which are the most important. The most numerous group in terms of species are representatives of the subfamily *Pimplinae*, whose representatives parasitize beetles, butterflies and *Hymenoptera*. (Only some species from the tribe *Polysphinctini*, for instance, of the genus *Clistopyga*, are as has already been mentioned exoparasites of spiders or alternatively their larvae live in the egg sacs of spiders.) Common parasitoids of harmful species of butterflies are numerous representatives of the genus *Pimpla*, which parasitize the pupae of forest pests such as rollers, nun moths, geometrids, tent caterpillar moths and allies, bagworm moths, etc. The most frequent species are *Pimpla instigator* L., with larvae living as endoparasites, for instance, in the pupae of the gypsy moth *Lymantria dispar* L., and *Pimpla turionellae* L., a parasitoid of the green oak leaf roller *Tortrix viridana* L., the European pine shoot moth *Rhyacionia buoliana* D.SCH., *Thaumatopoea processionea* L. and the fall webworm *Hyphantria cunea* DRURY. An important parasitoid of the pupae of the green oak roller and *Choristoneura murinana* HBN. are the similar species *Apechthis rufata* GMEL. (Tab. 27, Figs. d and e) and the related species *A. quadridentata* THOMS. They occasionally also parasitize the cocoons of the fox-coloured saw-fly *Neodiprion sertifer* GEOFF., the pine saw-fly *Diprion pini* L. and other saw-flies. It is remarkable that *A. rufata* GMEL. learns to differentiate between strains of the host. Thus one specialized on hosts from broad-leaved trees does not parasitize pests of conifers and vice versa. Frequent parasitoids of species of rollers living a concealed way of life are ichneumonids of the genus *Itoplectis*, mainly *I. alternans* GRAV. and *I. maculator* F. (Tab. 27, Figs. b—c). The latter species can exhibit secondary parasitism since it willingly attacks not only phytophagous insects but also tachinid-flies and also even ichneumonids. Un-

der conditions where this species had a selection of hosts, it parasitized only 1 % of the pupae of the green oak leaf roller and 12 % of the pupae of *Choristoneúra murinana* HBN. but 30 % of the cocoons of the ichneumonid *Cephaloglypta murinanae* BAUER (Tab. 27, Fig. g).

The subfamily *Pimplinae* also includes an important group of parasitoids, particularly of the genera *Dolichomitus* (Tab. 26), *Neoxorides* and *Ephialtes*, with attack xylophagous insects. Their larvae parasitize the larvae of wood-boring beetles. Common species are *Dolichomitus mesocentrus* GRAV. (Tab. 26, Figs. a—g) and *Neoxorides nitens* GRAV. which parasitize the larvae of the large popular longhorned beetle *Saperda carcharias* L., *Tetropium fuscum* F., *T. castaneum* L. and other species. This family also includes our largest ichneumonids from the genus *Rhyssa* (Tab. 24, Figs. a—d) and *Megarhyssa* which are exoparasites on the larvae of horn-tails (*Sirex, Urocerus* and *Tremex*). Another important genus in the *Pimplinae* subfamily is *Scambus* (Tab. 30, Fig. g). Its species *S. strobilorum* RATZ., *S. sagax* HTG. and *S. buolianae* HTG. are frequent parasitoids of the caterpillars of rollers, mainly the European pine shoot moth *Rhyacionia buoliana* D.SCH., *Petrova resinella* L. and also *Exoteleia dodecella* L.

The subfamily *Tryphoninae* is highly specialized in its selection of hosts. In this subfamily are species which only have saw-flies as hosts dominate. *Ctenochira* is the main economically important genus. Its species parasitize *Pachynematus montanus* HTG., *Pristiphora abietina* CHRIST. and *Pontania viminalis* L. Representatives of the genus *Erromenus* (Tab. 31, Fig. c) also parasitize saw-flies of the genus *Pristiphora*. The highly decorative, yellow-black species of the genus *Exenterus* (Tab. 31, Fig. f) are parasitoids of the pine saw-fly *Diprion pini* L., the fox-coloured saw-fly *Neodiprion sertifer* GEOFF. and *Gilpinia polytoma* HTG.

A particularly important group of parasitoids are ichneumonids of the genus *Phytodietus* (Tab. 27) since they are often the dominant parasitoids of forest pests. The species *P. polyzonias* FÖRST. (Tab. 27, Fig. a) often parasitizes the caterpillars of rollers, mainly the oak leaf roller and *Choristoneura murinana* HBN. The relatived species *P. griseanae* KERR. is an important parasitoid of *Zeiraphera diniana* GN.

Representatives of the subfamily *Xoridinae* exclusively parasitize the larvae of xylophagous species from the families of capricorn beetles and *Buprestidae*. Their females search for larvae of these beetles, which are also hidden beneath the strong bark of the stems and branches, and with admirable force pierce them with their ovipositor. Species of this subfamily have antennae, the last segments of which have sensils that make it possible for them to find exactly where the host larva is located. The most frequent species is *Xorides filiformis* GRAV. (Tab. 24, Fig. e), which parasitizes larvae of capricorn beetles of the genera *Ergates, Phymatodes, Callidium, Plagionotus, Rhagium*, etc. Another frequent species, *X. praecatorius* F., lives in the same way (Tab. 24, Figs. f—h).

The subfamily *Gelinae* includes species which have a broader spectrum of hosts and they are important parasitoids not only of saw-flies but also of some species of butterflies. Saw-flies of the family *Diprionidae* are parasitized by the known species *Endasys erythrogaster* GRAV. (Tab. 30, Figs. e—f) and *Agrothereutes adustus* GRAV. To the contrary, representatives of the

genera *Pycnocryptus, Ischnus* and *Itamoplex* are important parasitoids of the caterpillars of *Lasiocampa quercus* L., the gypsy moth *Lymantria dispar* L. and the pine beauty *Panolis flammea* D.SCH.

Representatives of the subfamily *Banchinae* are regular parasitoids of harmful forest rollers and some species are bound to only certain species of roller. The species *Cephaloglypta murinanae* BAUER (Tab. 27, Fig. g) is a monophagous parasitoid of *Choristoneura murinana* HBN. Often up to a half of the pupae of this roller are parasitized. Other frequent species are representatives of the genus *Lissonota* (Tab. 30, Figs. a—d), mainly the species *L. dubia* HOMGR., which parasitizes not only the green oak leaf roller and *Choristoneura murinana* HBN. but also other species, such as *Epinotia nigricana* H. SCH. and *Zeiraphera rufimitrana* H. SCH.

Species of the genus *Banchus* (Tab. 29, Figs. g—h) are again known parasitoids of various species of noctuid moths. *B. pictus* F. and *B. monileatus* GRAV. are often parasitoids of the pine beauty. If the females of these ichneumonids deposit eggs repeatedly into one caterpillar, often sepsis occurs due to an infection by microorganisms.

Included among the important parasitoids of harmful species of saw-flies are species of the subfamily *Ctenopelmatinae.* These are mainly *Lamachus eques* HTG. and *L. frutetorum* HTG., which attack the larvae of the pine saw-fly and the fox-coloured saw-fly. Another important species parasitizing the same hosts is *Lophyroplectus luteator* THNB. (Tab. 31, Fig. e), which is striking because of its pronounced sclerite under the pterostigma of the forewing.

Representatives of the subfamily *Cremastinae* are mostly forest steppe species. Some species, for instance, *Pristomerus vulnerator* GRAV., which is striking in that it has a tooth on the hind femora (Tab. 29, Figs. a—b), and *Temelucha buoliana* CURT. (Tab. 29, Figs. e—f) are common parasitoids of the European pine shoot moth. The second species was successfully introduced to North America (under the name *Cremastus interruptor* GRAV.).

The subfamily *Campopleginae,* since it includes the *Diadegma* and *Hyposoter* genera, belongs to the group of important parasitoids of many species of minute butterflies, the so-called microlepidoptera. Their taxonomy, since these are generally very tiny, has, of course, been little determined and for this reason many data in the literature are incorrect. The same is also true for representatives of the genus *Delopia,* of which the species *D. oxyacanthae* BOIE (Tab. 29, Figs. c—d) is an important parasite of numerous species of geometrids.

The ochre-yellow coloured ichneumonids from the *Ophioninae* subfamily are striking frequent parasitoids of forest pests. At night they fly towards light sources and because of this are particularly striking. A typical characteristic of these ichneumonids is the vaulted ocelli. *Ophion luteus* L. and *O. minutus* (KRIECHB.) (Tab. 29, Fig. i) often parasitize the caterpillars and pupae of a pest of broad-leaved trees which is common everywhere, the winter moth *Operophtera brumata* L. The species *Enicospilus ramidulus* L. (Tab. 28, Figs. c—d), which also often flies towards light during summer, is striking due to the free sclerites of its forewings. Besides other hosts, it is an important parasitoid of the pine beauty. Its sickle-shaped abdomen and crocked ovipositor allow this ichneumonid to stretch its abdomen

around underneath its body and deposit eggs into places which it examines using its long antennae.

A numerous group of parasitoids of forest pests is the subfamily *Metopiinae* which parasitizes species of the families of rollers and ermine moths. Of most importance are representatives from the genera *Chorinaeus, Metopius, Exochus, Triclistus* and others. In caterpillars and pupae of the feared grey larch tortrix the three following important parasitoid species were found: *Chorinaeus talpa* HAL., *Ch. funerbris* GRAV. and *Triclistus podagricus* GRAV. (Tab. 28, Figs. a—b). Parasitoids of *Choristoneura murinana* HBN. are *Chorinaeus longicalcar* THOMS. and *Trieces tricarinatus* HOLMG. (Tab. 2g, Fig. h). The latter species is also the most frequent parasitoid of the caterpillars and pupae of the ermine moths, *Yponomeuta malinellus* ZELL. and *Y. padellus* L.

Ichneumonids of the subfamilies *Anomalinae* and *Ichneumoninae* have a wide spectrum of hosts. Some species mainly attack larger species of butterflies; for instance, *Heteropelma calcator* WESM. (Tab. 28, Figs. f—g) and the related species *H. amictum* F. are important parasitoids of the pale tussock moth *Dasychira pudibunda* L. and the sphinx moth *Sphinx pinastri* L. although they sometimes parasitize caterpillars of the pine looper moth *Bupalus piniarius* L. A similar broad spectrum of hosts is also found with *Therion circumflexum* L. and *Aphanistes armatus* WESM. The species *Trichomma enecator* ROSSI (Tab. 28, Figs. i—j), which is striking with its densely pubescent eyes, is a frequent parasitoid of the gypsy moth and the caterpillars of *Earias chlorana* L. To the contrary, the species *Habronyx canaliculatus* RATZ. Parasitizes only minute species of butterflies, mainly the numerous species of rollers of the genera *Archips* and *Grapholitha,* including the grey larch tortrix. A dominant parasitoid of the green oak leaf roller from the subfamily *Ichneumoninae* is *Phaeogenes invisor* THNB. (Tab. 28, Fig. e). Besides the above-mentioned species, the largest species of ichneumons from the genera *Protichneumon, Amblyjoppa* (Tab. 25, Figs. g—h) and *Callajoppa* (Tab. 25, Figs. e—f) are also specialized on caterpillars of the sphinx moth *Sphinx pinastri* L.

From the ichneumonids subfamilies mentioned above, it is obvious that representatives of some subfamilies have only a narrow spectrum of hosts or some species are strictly monophagous and parasitize only one certain species of pest. To the contrary, some forest pests, and this also includes very important species, are attacked by representatives of several subfamilies of ichneumonids, which possess a broad spectrum of hosts. These species are mainly important during outbreaks of forest pests. Besides this, the ichneumonids also have two subfamilies with larvae which live as secondary or even tertiary parasitoids in useful species of insects. This is mainly the subfamily *Diplazontinae.* Its representatives parasitize the larvae and pupae of flower-flies. The most frequent species is *Diplazon laetatorius* F. (Tab. 32, Figs. h—i), which is cosmopolitan. In the beginning its larva consumes the haemolymph and later the tissues of the host. The subfamily *Mesochorinae* is also exclusively hyperparasitic. Its species live as endoparasites in the larvae of ichneumonids, braconids and tachinid-flies. In this way, is often reduced and this forces experts on the biological control of forest pests to make long-term observations, usually during major outbreaks of the main forest pests.

Of advantage for the use of ichneumonids for biolog-

ical control of harmful insects is the large number of species and high flight activity which are demonstrated in the higher rate of parasitization in years when there is a low population density of the hosts. These properties are, of course, simultaneously unfavourable for their effectiveness during years when there is an outbreak of the pest because their population is pronouncedly reduced by constant overflights. In biological control based on the introduction of species, the ichneumonids seem to be less effective than braconids and chalcidflies. Although all of the biological control projects directed against harmful butterflies and saw-flies also take the use of ichneumonids into account, parasitization by ichneumonids is, as a rule, low because they are not concentrated on one species of host. For this reason, often when the target hosts are numerous, many individuals are not attacked by ichneumonids because they parasitize many other hosts during the migratory flights. This was obvious in Central Europe during the nun moth outbreak of 1917—1925, when only in those biotopes which were especially favourable for ichneu-

monids was the nun moth population density considerably lowered; in unfavourable biotopes, notably the drier biotopes, where there was heavy nun moth feeding, the parasitization of the nun moth was very low. For this reason, programmes of biological control can reckon on a higher effectiveness of ichneumons only at localities with the necessary forest stand density and sufficient air moisture. For most species, it is necessary to have a broader spectrum of hosts for as much as possible during the whole growing season. Monophagous species of ichneumons are advantageous if their life cycle and locality coincide with that of the host. If this is not the case, polyphagous species are more effective and reliable for the regulation of pest populations because they can lay eggs into several host species. When selecting ichneumons for introduction, it is necessary to consider the different trophic specialization of each species in the various distribution areas of the pest; ichneumons can have different levels of effectiveness in different geographical territories after introduction into a new environment.

# BRACONIDS

The Braconidae family (Tab. 33—34) is one of the largest and most important groups of Hymenoptera Apocrita. Together with the family of ichneumonids (Ichneumonidae) and some further smaller families, they form the large superfamily Ichneumonoidea. Ichneumonids and braconids are two closely related families. The size of the body is not a reliable difference between them. Braconids have the majority of the more minute forms and ichneumonids the more robust forms but large species of braconids and, to the contrary, very tiny ichneumonids are not exceptional (Tab. 33, Fig. g). The only reliable differentiation characteristics of braconids are the single transverse vein in the forewing — ichneumonids have two — and the immobile connection between the second and third tergites of the abdomen — ichneumonids have a mobile connection.

Braconids constitute a large family in terms of the number of species: in Central Europe, we know about 1500 species. Each new revision of the group of species, genus or higher taxa brings descriptions of new species as well as new genera and higher taxonomy levels. Some subfamilies of braconids are still not sufficiently well-known and likewise the division into subfamilies is not definite. This naturally makes their exact identification difficult and even in relatively well-advanced Europe (in comparison with other geographical world regions), there are only a few specialists. A modern identification publication for the whole family is not available — the last one of this type was published at the end of the last century in France (MARSHALL, 1888—1897). More recent publications such as Opuscula braconologica written by FAHRINGER (1928—1948) and TELENGAS work (1936—1955) are out-of-date and the newest SHENEFELT's catalogue (1969—1978) cannot be used for identification. For this purpose, only revisions of the individual subfamilies, related groups and genera by various authors are satisfactory. However, the revisions do not at all cover the whole family.

The differentiation between some minute and mutually very similar braconids is especially difficult. So, for example, Figs. 25 to 29 show that for the genus Apanteles, which has many tens of minute species, the most important species characteristics are hidden on the first three tergites of the abdomen.

The majority of braconids are 2 to 4 mm long; they are little wasps of mostly a single colour, black or brown, which may be found during sunny weather on the flowers of Umbelliferae or other plants where they feed on nectar. Their females have ovipositors of various lengths from very short to very long (for instance, one tropical species has an ovipositor which is up to 14 times longer than the body). In those species whose larvae develop on the exterior of the host's body, the so-called ectoparasitic development, the ovipositor is connected with the poison gland. When stung by the ovipositor, the host is paralyzed by the poison and the female deposits her egg or eggs on it. The emerged larvae then suck on the body contents of the immobilized host larva or caterpillar. This is the life cycle of the more primitive subfamilies of braconids. Their species mostly parasitize the larvae of living hosts concealed, for instance, in wood, beneath bark, in leaves, cocoons, mines, etc.

More advanced groups of braconids parasitize the inside of the host (endoparasitism). Their ovipositor is adapted so that stinging and egg deposition into the body of the host cause the minimum of disturbance to its life processes. This is mainly necessary with those species of braconids which lay their eggs in the egg of the host for instance, species of the subfamily Microgastrinae. The postembryonic development of their egg, larva and sometimes the pupa practically occurs in parallel with that of the host. A necessary requirement for this is the normal development of the host. The disturbance of this development could jeopardize the braconids. The braconid larva mainly consumes the fatty tis-

sues of the host and avoids its vital organs so that the development is minimally disturbed. A parasitized host larva is only a little retarded in its growth in comparison with an unparasitized larva. When the larva of a braconid parasitizes the host adult, it feeds on the fatty tissues of the gonads and thus sterilizes the host.

Since a braconid larva lives mainly as a parasitoid, this is a very important active development stage which requires protection. The larvae of braconids are legless and have head capsula. The number of larval instars is not the same for the whole family. With the ectoparasitic forms, there are five larval instars and the endoparasitic forms have three to four. The larvae of the first instar have strikingly large head capsula with robust mandibles. The mandibles are obviously a defense adaptation to assist in the struggle for life when the larva destroys either all the larvae of other species of parasitoids in the host in the case of multiparasitism or the larvae of its own species in the case of superparasitism. These robust mandibles are mainly typical of solitary species. They are not usually present in gregarious or polyembryonic species. The larvae also often possess special characteristics at the end of the abdomen, either in the form of a tail or a vesicle. The former is obviously important for the movement of the larvae while the abdominal vesicle is a caudal appendage of the proctodaeum and probably serves for breathing. These two formations are typical only of the endoparasitic species and diminish in the course of the larval development: the largest occur in the first instar and disappear in the last instar.

In more advanced forms of braconids, the egg also lives parasitic life. During postembryonic development, the egg increases several times in size due to the host — in some species with a trophic egg membrane, up to a hundred times.

Braconids usually pupate outside the host. Some subfamilies also pupate, of course, in the host pupae (for instance, the subfamilies *Opiinae* and *Alysiinae*) in the puparium of flies. From this point of view, the *Rogadinae* subfamily is interesting. The excretions of the larvae of its last instar mummify the host larva and then they pupate inside this mummy (Tab. 38, Fig. d). The majority of braconids spin special cocoons for pupation. Their form, surface, colouring and location as well as the emergence hole are specific for each species and are shown in this publication. Species pupating in litter have, as a rule, rough-walled cocoons which are often multilayered (the innermost layer is fine and the surface layer is felt-like). To the contrary, the cocoons hidden in the galleries of hosts living in wood or beneath bark, and also in their webs or mines, are very fine and thin-walled. Braconids parasitize free-living hosts and also mostly pupate freely. To conceal their cocoon, some species use mimicry either in its shape (e.g., *Microplitis sordipes* NS. imitates the poplar bud), its surface texture (e.g., the longitudinally ribbed cocoon of *Microplitis naenia* NIX. resembles the seed of a plant, see Tab. 33, Fig. f), or its colour (e.g. the cocoon of *Microplitis ruricola* LYLE is the same green colour as the leaf onto which it is spun). Some species of the genus *Meteorus* hang their cocoons from fine fibres up to several centimetres long so that they are freely mobile. Most species spin their cocoon onto the remains of the host (for instance, Tab. 40, Figs. f—g) and gregarious species mostly spin a common cocoon from a common web

(Tab. 39, Fig. d) or at least spin the cocoons together. The aim of all of these adaptations is to protect the braconids against numerous species of hyperparasites, usually either ichneumons or chalcid-flies, which often considerably reduce the populations of braconids.

Adult braconids do not live a parasitic life: they do not eat food at all or if they do, it is only the nectar of flowering plants or honey dew. Only in some of the more primitive forms has it been observed that their females sting the host with their ovipositor and consume the body fluid which flows round the incision. It is interesting that the host is selected by the adult which otherwise lives freely, i.e. not parasitically. The females use their antennae to investigate the presence of hosts while the males use their antennae to search for females. It is obvious that inherent instincts are applied in the decision of whether a certain host is attractive to the female or not. The systematics is not the only decisive factor; of the same importance is the development stage of the host. Braconids are divided into several groups according to the stage of host in which the braconid female deposits the egg and that at which the larva of the last instar leaves, which may in some subfamilies even be the adult braconid (i.e., according to the time at which the development of the braconid is closely associated with its host):

egg — larval group (e.g., the subfamilies *Cheloninae, Adeliinae* and *Ichneutinae*);

egg— pupal group (e.g., some species of the genera *Opius, Coelinius* and *Symphya*);

larval group (e.g., the subfamilies *Doryctinae, Braconinae, Rogadinae*, etc.);

larval—pupal group (e.g., species of the subfamilies *Opiinae, Alysiinae*, etc.);

nymphal—imaginal group (e.g., species of the genera *Aridelus, Leiophron*, etc.) and

imaginal group (e.g., species of the subfamilies *Euphorinae* and *Leiophroninae*).

Since the development of the braconid larva always ends fatally for its host, the phenomenon is not typical of parasitism. Modern entomological literature defines entomophagous parasites as parasitoids so as to differentiate this type of parasitism. Braconids are divided according to the number of braconid individuals which may successfully develop in one host into solitary parasitoids (only one braconid can develop in the host) and gregarious parasitoids (more than one braconid in one host). Gregarious parasitism may be the result of the braconid female depositing more than one egg into one host at the same time or the phenomenon known as polyembryony. During the cleavage time, the polyembryonic egg divides into several independent eggs. From these eggs, normal larvae develop, which will always be of the same sex. Polyembryony occurs, as a rule, with some genera of braconids, for instance, *Macrocentrus linearis* (NS) (Tab. 39, Figs. c—d). All these relationships between the parasitoid braconids and their relevant hosts were stabilized during phylogenesis and are, therefore, specific for an individual species.

The species and number of braconids in a certain biotope are conditioned mainly by the occurrence of the hosts which their larvae parasitize and, further, by the sources of food for their adults, which are the nectar of flowering plants and honey dew. Braconids are very sensitive to the majority of insecticides currently in use and for this reason high numbers of species and individ-

uals are present only in the biocoenoses of crops which have remained chemically untreated for several years, i.e., mainly in forest stands. The richer a certain biocoenosis is in terms of insects, the more varied will be the representatives of braconids and vice versa. It may be concluded that the majority of braconid species in Central Europe are predominantly or at least partially bound to forest ecosystems or their borders. In these ecosystems, they have an important role in the natural regulation of forest pests. Due to the large diversity of their host relationships, braconids assert themselves in virtually the majority of the main groups of harmful forest insects. It should be pointed out that braconids have not been found to exhibit either hyperparasitism (as is so often the case with, for example, ichneumons or chalcid-flies) — with few exceptions — or parasitization of beneficial species of insects. From the point of view of forest protection, braconids can, therefore, be unambiguously assessed as an important group of entomophagous insects.

As parasitoids of beetles (*Coleoptera*), braconids mostly parasitize the host larvae; certain species also parasitize the adults. Their hosts, with the exception of some useful species (for instance, the ladybird beetles of the *Coccinellidae* family), are only harmful species of beetles.

Species from the subfamilies *Braconinae* and *Doryctinae* have been reared in laboratories from parasitized flatheaded woodborers (*Buprestidae*): for instance, *Atanycolus initiator* F. (Tab. 36, Fig. c.) from *Phaenops cyanea* F., *Eucorystoides aciculatus* REINH. from *Agrilus elongatus* HRBST. and finally *Ontsira antica* WOLL. (Tab. 36, Fig. d) from *A. viridis* L.

Braconids are also important entomophagous parasites of *Anobiidae*. The ectoparasite *Bracon pineti* THOMS. was one of the main parasitoids of *Ernobius abietis* F. in practically all samples of cones examined. Here and there among them, the endoparasite *Baeacis abietis* RATZ. was also recorded. *B. pineti* THOMS. has also been recorded on other species of the genus *Ernobius*. Species of the genus *Spathius* parasitize beetles of the genus *Anobium*, for instance, the ectoparasite *S. exarator* L. was found on the furniture beetle *Anobium punctatum* DEG.

Braconids, mainly ectoparasites from the subfamilies *Braconinae* and *Doryctinae*, also often parasitize the larvae of longhorned beetles (*Cerambycidae*). From the *Braconinae* subfamily, this includes species of the genus *Atanycolus*: e.g., *A. initiator* F. (Tab. 36, Fig. c) on *Tetropium* spp., *Acanthocinus aedilis* L., *Asemum striatum* L. and *Rhagium* spp.; *A. neesii* MARSH. on *Tetropium* spp., *Acanthocinus aedilis* L., *Criocephalus rusticus* L., *Saperda carcharias* L. and *Pyrrhidium sanguineum* L.; and *A. denigrator* L. on *Tetropium* spp., *Rhagium* spp. and *Saperda populnea* L.. Other species from this subfamily include *Cyanopterus flavator* F. (on *Pogonochaerus fasciculatus* DEG.) and *Iphiaulax impostor* SCOP. (on *Monochamus* spp.). The more frequent species found are from the *Doryctinae* subfamily, particularly from the genus *Doryctes*: e.g., *D. mutillator* THUNB. (on *Tetropium* spp. and *Clytus lama* MULS); *D. pomarius* REINH. and *D. undulatus* RATZ. (on *Pogonochaerus* spp.); *D. planiceps* REINH. (on *Saperda populnea* L.); and *D. leucogaster* NS. (Tab. 36, Fig. b) (on *Rhagium* spp.). Further *Doryctinae* species are from the genus *Ontsira*, e.g., *O. antica* WOLL. (Tab. 36, Fig. d) on *Pyrrhidium sanguineum* L. and *Phymatodes*

*testaceus* L.), *O. ignea* RATZ. (on *Pogonochaerus* spp.), and *O. imperator* HAL. (on *Acanthocinus aedilis* L. and *Leptura* spp.), and finally *Rhoptrocentrus piceus* MARSH. which is the main parasitoid of the old house-borer *Hylotrupes bajulus* L. Typical parasitoids of the larvae of longhorned beetles are also endoparasitic species of the subfamily *Helconinae*, from four genera: *Helcon*, e.g., *H. tardator* NS. (Tab. 35, Figs. b) (on *Clytus lama* MULS., *Callidium spp.*, *Pyrrhidium sanguineum* L. and *Phymatodes testaceus* L.) and *H. redactor* THUNB. on *Callidium* spp.; *Wroughtonia*, e.g., *W. dentator* F. on *Tetropium* spp. and *Monochamus* spp.; *Aspicolpus*, e.g., *A. carinator* E. (Tab. 35, Fig. a) on *Xylotrechus rusticus* L. and *Pyrrhidium sanguineum* L.; and *Cenocoelius*, e.g., *C. secalis* L. on *Pogonochaerus* spp.

Hitherto no species of braconids have been reported from the larvae of chrysomelids. The only information is on parasitization by the species *Perilitus brevicollis* HAL. of adults of *Melasoma aenea* L.

Braconids also assert themselves to an important extent in the regulation of harmful weevils. An important entomophagous parasite of the larvae of the large brown pine weevil, *Hylobius abietis* L., is the gregarious ectoparasite *Bracon hylobii* RATZ. (Tab. 33, Figs. e—h, Tab 37, Fig. f). Many weevils (*Pissodes* spp.) are parasitized by endoparasitic species of the genera *Eubazus*, and *Allodorus*: e.g., *E. atricornis* (RATZ.) (Tab. 37, Figs. c—e.), (on *P. piceae* ILL., *P. piniphilus* HERBST., *P. notatus* F. and *P. validirostris* GYLL.), *E. robustus* RATZ. and *E. mucronatus* THOMS. (on *P. notatus* F.), and *Allodorus*, e.g., *A. semirugosus* NS. parasitizes *P. harcyniae* HERBST. Ectoparasitic braconids are entomophagous parasites of weevils.

These include, for instance, *Coeloides foersteri* HAE-SELB. on *P. piceae* ILL. and *C. sordidator* RATZ. on *P. notatus* F., *P. harcyniae* HERBST., *P. piniphilus* HERBST., *P. pini* L. and *P. validirostris* GYLL. On beetles of the genus *Magdalis*, species of the subfamily *Helconinae* are found: e.g., *Eubazus rugosus* RATZ. on *M. violacea* L. and *M. armigera* GEOFFR., *E. longicaudis* RATZ. on *M. ruficornis* L. and *Cenocoelius analis* NS. on *M. armigera* GEOFFR. and *M. ruficornis* L. Members of the *Doryctinae* subfamily also parasitize beetles, e.g., *Spathius brevicaudis* RATZ. parasitizes on *M. armigera* GEOFFR. and *M. ruficornis* L.). The parasitoids of the larvae of the poplar and willow borer *Cryptorrhynchus lapathi* L. are mainly ichneumons; the only braconid species found is *Bracon immutator* NS. To the contrary, the most frequent parasitoids on the mining larvae of curculionids from the genus *Rhynchaenus* are braconids. The parasitoids of *Rhynchaenus fagi* L. are *Triaspis pallipes* NS. and *Colastes braconius* HAL., while *Eubazus minutus* RATZ. is a parasitoid of *R. quercus* L.

The most important family of pest beetles from the forestry point of view is *Scolytidae*, the bark beetles. Overall, for this family, braconids are the most important entomophagous parasitoids, mainly the ectoparasitic species of the subfamilies *Braconinae* and *Doryctinae*. Species of the genus *Coeloides*, from the *Braconinae* subfamily, are virtually specialized only on bark beetles, mostly each species parasitizing bark beetles of a certain host tree. So *C. abdominalis* ZETT. is found on pine (parasitizing *Blastophagus piniperda* L., *B. minor* HART. and *Ips sexdentatus* BÖRN.); *C. bostrichorum* GIR. (Tab. 34, Figs. c—d) on spruce (*Ips typographus* L. and *Pityogenes chalcographus* L.) and silver fir (*Pityokteines*

*curvidens* GERM.); *C. filiformis* RATZ. (Tab. 37, Figs. a—b) and *C. melanotus* WESM. on ash (*Hylesinus fraxini* PANZ. and *H. crenatus* F.); *C. scolyticida* WESM. on elm (*Scolytus scolytus* F., *S. multistriatus* MARSH. and *S. pygmaeus* F.); and *C. ungularis* THOMS. on birch (*S. ratzeburgi* JANS.). The subfamily *Doryctinae* is represented by the genus *Dendrosoter*, mainly two species: *D. midendorffii* RATZ. (Tab. 34, Figs. a—b) mainly parasitizes bark beetles on coniferous trees (for instance, *Blastophagus piniperda* L., *B. minor* HART., *Polygraphus polygraphus* L., *P. grandiclava* THOMS., *Pityokteines curvidens* GERM. and *Ips typographus* L.), whereas *D. protuberans* NS. (Tab. 36, Fig. a) parasitizes bark beetles on broad-leaved trees (for instance, *Scolytus scolytus* F., *S. laevis* CHAP., *S. multistriatus* MARSH., *S. pygmaeus* F., *S. intricatus* RATZ., *Hylesinus fraxini* PANZ., *Pteleobius vittatus* F., and *Xyleborus dispar* F.). A further species *D. hartigii* RATZ. parasitizes *Crypturgus cinereus* HERB. and *Pityogenes chalcographus* L. Species of the genus *Dendrosoter* have always been less advanced in this respect in comparison with braconids from the genus *Coeloides*. The regular occurrence of *Ecphylus silesiacus* (RATZ.) (Tab. 36, Fig. e) from the same family has also been recorded; it is morphologically quite varied and parasitizes a large number of bark beetles but always only in low numbers. Species of the genus *Spathius* are also occasional parasites of bark beetles, for instance, *S. rubidus* ROSSI. (Tab. 37, Fig. g) on *Scolytus pygmaeus* F. and *Hylesinus fraxini* (P.). Besides these ectoparasites of the larvae of bark beetles, endoparasitic species of braconids from two genera, mainly from *Ropalophorus* and also from *Cosmophorus*, also regulate the adults. *Ropalophorus clavicornis* WESM. (Tab. 34, Figs. e—g) is a frequent parasitoid of the hibernating imagines of *Ips typographus* L. while *Cosmophorus klugii* RATZ. (Tab. 39, Fig. b and Fig. 30) parasitizes *Polygraphus polygraphus* L., *C. regius* NIEZ. parasitizes *Dryocoetes hectographus* REITT., and *C. cembrae* RUSCH. parasitizes *Pityogenes conjunctus* REITT. and *P. vorontzovi* JAC. Braconids are of varied importance for individual families of beetles. However, they are of utmost importance for the longhorned and bark beetles a high percentage of which they may parasitize.

Braconids parasitize moths either as ectoparasites or mostly as endoparasites, and only their caterpillars, often being more important than ichneumonids or chalcid-flies.

Some species (from the subfamily *Cheloninae*) may deposit their eggs in the butterfly eggs but their larvae develop first in the caterpillars. With mining species of butterflies the dominant parasitoids are chalcid-flies but braconids also occur. The ectoparasitic species *Colastes braconius* HAL. (Tab. 33, Figs. c—d) parasitizes a whole range of mining insect from several orders and, therefore, also butterflies of some families: for instance, *Tischeria ekebladella* BJERK., lithocolletids (e.g., *Lithocolletis faginella* ZELL.), etc. Some species of the genus *Lithocolletis* are also known to be parasitized by representatives of the genus *Apanteles*, for instance, *Ap. circumscriptus* NS. (on *L. populifoliella* TR.) and *Ap. pedias* NIX. on *L. comparella* DUP. The most frequent parasitoid of *Bucculatrix ulmella* ZELL. is *Ap. moldavicus* TOB. Braconids are of less importance for gelechiid moths: *Macrocentrus bicolor* CURT. is a parasitoid of *Diurnea phryganella* HB. and *D. fagella* F., and *Exoteleia dodecella* L. is parasitized by *Ap. lemariei* NIX., *Bracon stabilis* WESM. and *Macrocentrus linearis* (NS.) (Tab. 39, Figs. c—d). Parasitizing

braconids of casebearer moths (*Coleophoridae*) are of varied importance. For example, in the case of the larch casebearer (*Coleophora laricella* HB.), the braconid *Agathis pumila* RATZ. is the second most important parasite. However, with other casebearer moths, the braconids are the most important parasitoids: on casebearer moths living on oak (*C. lutipennella* ZELL. and *C. flavipennella* DUP.), we find *Agathis lugubrator* (RATZ.) (Tab. 39, Fig. a), *Baeognatha nigra* TEL. (Tab. 39, Figs. e—f) and the ectoparasite *Bracon osculator* NS. Similarly, on *Blastotere glabratella* ZELL. of the argyresthiids family, we find that the braconid *Apanteles credne* NIX. is the main parasitoid.

Even in the case of the large family of *Tortricidae*, the evaluation of braconids as parasitoids is not simple. With most tortricids, it is the parasitization of the pupae which is of more importance but braconids do not take part in this. They often have an important role as parasitoids of the caterpillars. It is possible to divide them into two groups. The first is that of the more polyphagous species like *Macrocentrus linearis* (NS.) (Tab. 39, Figs. c—d), the solitary species *Charmon extensor* L. (Tab. 38, Figs. e—f), *Meteorus pallipes* WESM. and the ectoparasite *Oncophanes laevigatus* (RATZ.) (Tab. 38, Figs. a—b) which are found on many species of tortricids (for instance, *Pandemis* spp., *Choristoneura* spp., *Archips* spp., *Tortrix* spp. and *Aleimma loefflingiana* L.) but virtually only on broad-leaved trees with the exception of the species *Ch. extensor* (L.), which also occurs on conifers. The second group is represented by braconids which are more specific in the selection of their host; these are mainly from the genera *Apanteles*, *Microgaster*, and possibly also *Meteorus* and *Ascogaster*. *Apanteles xanthostigma* HAL. and *Ascogaster rufidens* WESM. (Tab. 38, Fig. g) parasitize tortricids of the genus *Pandemis*; *Ap. murinanae* ČAP. ZW. (Tab. 41, Fig. c) parasitizes *Choristoneura murinana* HBN.; the gregarious species *Ap. ater* RATZ. parasitizes tortricids of the genus *Archips*; *Microgaster hospes* MARSH. (Tab. 38, Fig. h) parasitize *Aleimma loefflingiana* L. and *Tortrix viridana* L.; *Ap. emarginatus* WESM. and *Meteorus ictericus* NS. parasitize *T. viridana* L.; *Orgilus obscurator* NS. (Tab. 43, Figs. e—f) and *Macrocentrus buolianae* EADY et CL. (Tab. 43, Figs. g—h) parasitize the European pine shoot moth *Rhyacionia buoliana* D.SCH.; *Ap. longicauda* WESM. parasitizes *Epinotia nigricana* H. SCH.; *Ap. tedellae* NIX. parasitizes *Epinotia tedella* CL.; *Ap. lineipes* WESM. parasitizes *Zeiraphera rufimitrana* H. SCH. and *Z. diniana* GN.; and finally *Braunsia rufipes* NS. and *Agathis dimidiator* NS. parasitize *Spilonota ocellana* D.SCH.

Two species of braconids are typical for caterpillars of clear-winged moths, *Macrocentrus marginator* NS. and *Apanteles iarbas* NIX., which are known from some species of caterpillars (for instance, *Aegeria formicaeformis* ESP.). Likewise in *Phycitidae* caterpillars, specialized species of braconids dominate, for instance, *Zele chlorophthalmus* SPIN., *Microtypus wesmaelii* RATZ. and *Macrocentrus flavus* SNELL. on *Acrobasis* spp. and *Phycita roborella* D. SCH.; the most frequent of the polyphagous species is the gregarious *Macrocentrus linearis* NS. (Tab. 39, Figs. c—d).

Specialized species of braconids also dominate on geometrid caterpillars. Some species of geometrid moths are hosts of a narrow range of monophagous parasites: e.g.; geometrids of the genus *Alsophila* are hosts of the braconid species *Acampsis alternipes* NS.

(Tab. 33, Figs. a—b); the geometrid *Thera variata* D. SCH. hosts several parasitoids like *Aleiodes circumscriptus* NS., *Apanteles pinicola* LYLE, *Protomicroplitis calceatus* HAL. and *Meteorus lionotus* THOMS. (Tab. 43, Figs. c—d), the geometrid *Semiothisa signaria* HB. hosts two braconid species *Aleiodes cantherius* LYLE and *Meteorus pallidus* NS.; and finally the geometrid *Peribatodes secundaria* ESP. hosts the braconid *Apanteles vitripennis* HAL. Other species of braconids are typical parasitoids of geometrid moths and, therefore, it is possible to find them on many species: *Apanteles caberae* MARSH. on *Bupalus piniarius* L., *Ennomos erosaria* D. SCH. and *Agriopis aurantiaria* HB.; *Ap. andromica* NIX. on *Erannis defoliaria* CL. and *Cyclophora punctaria* L.; *Ap. enephes* NIX. on *Operophtera brumata* L., *Apocheima pilosaria* D.SCH., *Er. defoliaria* CL. and *B. piniarius* L.; *Ap. jucundus* MARSH. on *O. brumata* L and *Cycl. punctaria* L.; *Ap. praepotens* HAL. (Tab. 42, Figs. e—f) on *O. brumata* L., *Er. defoliaria* CL. and *Agriopis* spp.; and finally the gregarious species *Ap. spurius* WESM. (Tab. 42, Figs. g—h) on *Biston stratarius* HUFN. and *Campaea margaritata* L.

Gregarious species of braconids which are mostly highly specialized occur frequently on noctuid caterpillars *(Noctuidae)*. These gregarious species include: *Apanteles tibialis* CURT. which is a parasitoid on *Autographa gamma* L.; *Ap. scabriculus* REINH. on *Earias chlorana* L.; *Ap. congestus* NS. on *Apatele spp.; Ap. brevicornis* WESM. and *Meteorus gyrator* THUNB. on *Ipimorpha retusa* L., *Microplitis mandibularis* THOMS. on *Conistra vaccinii* L.; and finally *Meteorus longicornis* RATZ. on *Pseudoips fagana* L. Of the solitary braconid species, the more important ones are, for instance, *Microplitis naenia* NIX. (Tab. 33, Figs. e—f) on *Orthosia* spp., *Conistra vaccinii* L and *Cosmia trapezina* L.; *M. sordipes* NS. and *M.*

*fumipennis* RATZ. on *Apatele* spp.; *M. tuberculifera* WESM. and *Apanteles hyphantriae* RIL. on *Orthosia* spp.; *Earinus nitidulus* (NS.) (Tab. 40, Figs. a—b), on *Orthosia spp.* and *Conistra vaccinii* L.; *Zele albiditarsus* CURT. (Tab. 40, Figs. c—d) on *Orthosia stabilis* D. SCH. and *Panolis flammea* D.SCH.; *Meteorus pulchricornis* WESM. on *Conistra vaccinii* L., and finally *Meteorus scutellator* NS. on *Cosmia trapezina* L. The gregarious braconid *Apanteles isolde* NIX. parasitizes tetheids including the species *Cymatophorima diluta* D. SCH., *Polyploca ruficollis* F. and *P. ridens* F.

Braconids have an important role in the control of tussock moths (*Lymantriidae*) but only during periods of low population density. Thus, on the gypsy moth (*Lymantria dispar* L.), there are solitary species, for instance, *Apanteles melanoscelus* (RATZ.) (Tab. 41, Figs. d—e) and *Ap. porthetriae* MUES. (Tab. 41, Fig. a), which parasitize the younger instars; gregarious species, for instance, *Ap. liparidis* (BCHÉ) (Tab. 41, Fig. f and for a detail of the three tergites of the abdomen see Fig. 28) and *Ap. inclusus* RATZ., parasitize the older instars. A similar phenomenon is found with the browntail moth, *Euproctis chrysorrhoea* L., where the solitary braconid *Ap. lacteicolor* VIER. lives in the younger caterpillars (Tab. 42. Figs. c—d plus a detail of the three tergites of the abdomen of this species is given in Fig. 26), while the gregarious braconid *Ap. gastropachae* (BCHÉ) (Tab. 41. Fig. b and a detail of the first three tergites of the abdomen of this species is shown in Fig. 29) is found in the older caterpillars. In the goldtail moth (*Porthesia similis* FUES.), the gregarious species *Ap. pompelon* NIX. is found while, to the contrary, only the solitary species *Ap. melanoscelus* RATZ. (Tab. 41, Figs. d—e) and *Meteorus versicolor* WESM. (Tab. 40, Figs. e—g) occur on *Leucoma salicis* L. *Meteorus versicolor* WESM. is of only secondary importance for *Thaumatopoea processionea* L. An important gregarious endoparasitoid of *Eilema deplana* ESP. caterpillars is *Apanteles octonarius* RATZ. (Table 42, Figs a—b, and a detail of the first three tergites of the abdomen of this species is given in Fig. 27).

Braconids are parasites of only little importance for the family of notodontid moths (*Notodontidae*). For instance, the gregarious species *Apanteles affinis* NS. and *Aleiodes testaceus* F. (Tab. 38, Figs. c—d) occur on *Cerura vinula* L. Likewise the gregarious braconid *Ap. abjec-*

Fig. 25 Detail of the first three abdominal tergites of *Apanteles spurius* (WESM.)

Fig. 26 Detail of the first three abdominal tergites of *Apanteles lacteicolor* VIER.

Fig. 27 Detail of the first three abdominal tergites of *Apanteles octonarius* (RATZ.)

Fig. 28 Detail of the first three abdominal tergites of *Apanteles liparidis* (BCHÉ)
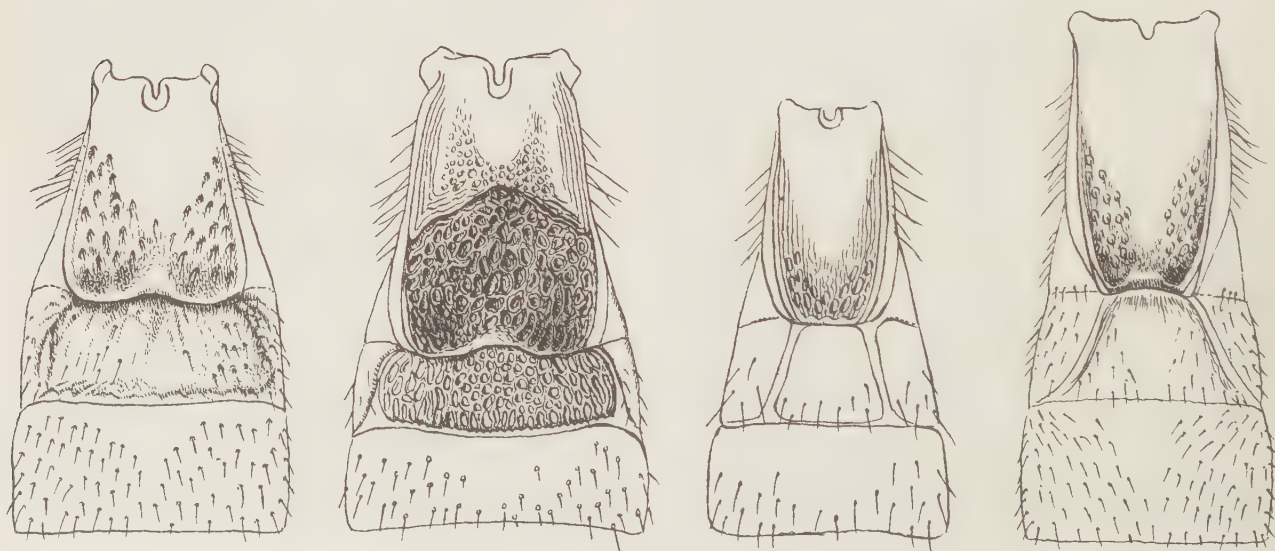
*tus* MARSH. parasitizes *Drymonia ruficornis* HUFN. and *Notodonta ziczac* L. The gregarious species *Ap. gastropachae* BCHÉ (Tab. 41, Fig. b and Fig. 29) is an important regulator of pests of the *Lasiocampidae* family, for instance, the lackey moth (*Malacosoma neustrium* L.) and *Eriogaster lanestris* L. The caterpillars of the black-veined white moth (*Aporia crataegi* L.) are parasitized by the gregarious braconid *Ap. pieridis* BCHÉ.

Braconids differ from ichneumonids in that they only marginally assist in the control of forest pests from the order *Hymenoptera*. Only the subfamily *Ichneutinae*, whose species are minute, is involved. Its species parasitize on saw-flies from the subfamily *Nematinae*.

As it has been stressed, braconids have adapted themselves to parasitization of many insect orders. Apart from the detailed information given above on beetles and butterflies, and *Hymenoptera* which include the most important pests of forest trees, other braconid hosts are species of the orders *Psocoptera, Heteroptera* (bugs), *Neuroptera, Raphidioptera* (snake-flies) and *Diptera* (flies). Species of these orders are, of course, from the point of view of forest protection either insignificant or possibly beneficial, or their harmful effects are not important, and for this reason their braconid parasitoids are not described in detail here.

# CHALCID-FLIES

The chalcid-flies *Chalcidoidea* comprise the most numerous group in terms of species of the *Terebrantia* suborder of *Hymenoptera*. This superfamily has in Europe alone some thousands of species and its taxonomy is the most difficult of the insect group, mainly because the species are very minute, often around 1 mm long. With many chalcid-flies, it has not hitherto been known which species they parasitize and, besides this, there are many herbivorous species, the larvae of which live in plant seeds. Many species are also hyperparasitic. Common characteristics of the majority of the species are a very simplified wing venation and a nice metallic body colour, very often with various textures on the thorax. Many species living in our country are of foreign origin, mostly of American provenance. These species were introduced either unintentionally by the transport plying between the continents or with the intention of introducing important parasitoids of some harmful insect species to Central Europe.

Fig. 29 Detail of the first three abdominal tergites of *Apanteles gastropachae* (BCHÉ)

Fig. 30 Detail of *Cosmophorus klugii* RATZ; front view of the head with closed (alove) and open (below) for mandibles grasping bark beetles



Of most importance for forest protection are representatives of the families *Torymidae, Encyrtidae, Pteromalidae* and *Trichogrammatidae* although this has not yet been fully assessed. They are without doubt of considerable importance for maintaining the natural balance of harmful insect en masse. Coloured pictures of representatives of the chalcid-flies are not available in any other Czech entomological literature. Due to the limited scope of this publication, only nine species have been selected.

The pteromalid *Tomicobia seitneri* RUSH. (Tab. 44, Figs. a—c) is an important parasite of scolytids. At the time of their swarming on stems, the female inserts her ovipositor into the sutures between the elytra on the host's body. The development of the larva takes some weeks. The adult pteromalids leave the bark beetle through a circular opening in the hind part of the abdomen (Fig. c). In regions of an outbreak of bark beetles, the parasitization by this species reached 80 %.

*Pachyceras xylophagorum* RATZ. (Tab. 44, Figs. d—e) deposits eggs into the mother galleries of bark beetles and only exceptionally through weak bark into the larval galleries of the bark beetles. It parasitizes many species of bark beetles (*Ips typographus* L., *Pityogenes bidentatus* L., *P. chalcographus* L., *P. guadridens* HERBST., *Myelophilus piniperda* L., *Polygraphus polygraphus* L., *Pithyophthorus micrographus* L., *Pityokteines curvidens* GERM., *Scolytus intricatus* RATZ. and *Xyleborus monographus* F.). *Rhopalicus tutella* WALK. lives the same type of life and parasitizes in a similar way. The female of this species deposits eggs directly into the larvae of bark beetles (Tab. 44, Fig. f—g) and is a typical parasite of bark beetles developing beneath thin bark (*Ips laricis* L., *I. cembrae* HEER, *Scolytus pygmaeus* F. and *Pityogenes pilidens* RTT.).

*Perniophora robusta* RUSCHKA (Tab. 45, Figs. e—g) is an important parasite of the lineate ambrosia beetle (*Xyloterus lineatus* OL.). The male is a bright metallic brown and the female metallic green. The eggs are laid in the galleries of the lineate ambrosia beetle on the surface of the larvae. Parasitization destroys up to 80 % of the larvae.

An important group of chalcids are the *Trichogrammatidae* which are parasitic on the eggs of butterflies. Two pictured species belong to this group. *Trichogramma evanescens* WESM. from the *Trichogrammatidae* family (Tab. 45, Figs. a—d) is an extremely small insect. only
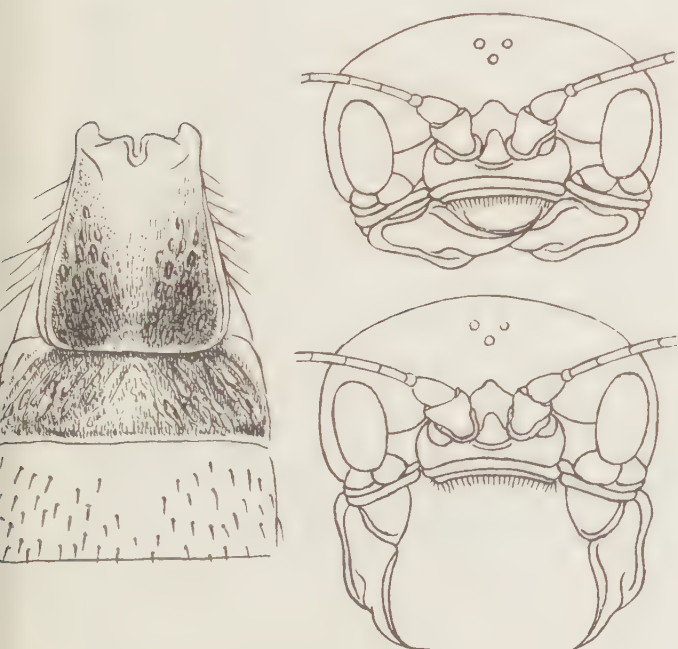
about 0.5 mm in length. It is a polyphagous parsite of the eggs of larger butterflies and saw-flies of the genus *Cephaleia*. The polyembryony (i.e., several adults from one egg) of this species is important. Similarly, *Eupelmus disparis* RUS. from the *Eupelmidae* family parasitizes the eggs of the pine beauty. The scelionid *Telenomus laeviusculus* RATZ. from the superfamily *Proctotrupoidea* (Tab. 45. Figs, h—i) is an important parasite of the eggs of the pine moth in the localities of its outbreaks.

One of our largest chalcid species is *Brachymeria intermedia* (NEES.) (Tab. 46, Fig. b). The strong femora on the hind legs of this species, which is not a good flier and moves slowly, help it to spring over long distances; this is of importance for protection against its natural enemies. This chalcid freqently parasitizes most the pupae (the eggs are deposited in the last instars of the caterpillars) of the gypsy moth, browntail moth and nun moth, as well as those of the fall webworm (*Hyphantria cunea* DRURY) introduced to Central Europe. If the outbreaks of the green oak leaf roller (*Tortrix viridana* L.) and of the tortricid *Aleimma loefflingiana* L. are repeated for some years, this chalcid becomes their main parasite together with the species *Eulophus larvarum* L. and *Pteromalus puparum* L. pictured on the same Table (Tab. 46, Figs. a and c).

*Pteromalus puparum* L. (Tab. 46, Fig. c) of the *Pteromalidae* family, which has numerous members (about 300 species in Europe), is perhaps the most abundant chalcid in Central Europe. It is a parasite of many species of caterpillars, mainly of the whites. Its control of the host is effective. The eggs are laid in the caterpillars and in the pupae while their skin is still soft. A large number of eggs is deposited in one pupa. After the emergence of the imagines, the pupa is perforated by numerous emergence openings.

# APHIDIIDS

Aphidiids (*Aphidiidae*) are minute parasitic *Hymenoptera*; they are close relatives of the braconids and are sometimes classified as their subfamily. One of main differing characteristics is the arrangement of the abdomen the second suture of which bends downward when necessary. The body of aphidiids is long, from one to several millimetres. The colouring is usually black to dark brown or a more or less yellow to yellow-brown (Tab. 47—48).

Aphidiids are specialized on aphids and are the main and most important group of parasites for this pest.

The larval development of aphidiids occurs in four stages. Prior to the end of the last stage, the full—grown larva bites the skin on the ventral side of the aphid and attaches itself using the excretions from its salivary gland, to the ground. Inside or beneath the skin of the dead aphid, it spins a web. The dead parasitized aphid obtains a characteristic blown appearance, also more changes its colour and is classified as a mummy. Mummified aphids are easily distinguishable in the colony.

The adult parasite bites a circular opening, which is used for emergence, in the mummy or in the independent cocoon. The circular cover is separated and very often broken off. This circular opening with regular borders and a cover which often falls off is characteristic for aphidiids, whereas their own parasites, i.e., hyperparasites of aphids, bite the emergence hole so that it has irregular borders and the cover is always missing (Tab. 48, Fig. e). In some cases, predators attack the mummified aphids (for instance, larvae of chrysopids) which suck on the mummies. After their attack, two or more minute openings remain in the mummies and the emergence hole of the parasite is missing (Tab. 48, Fig. e). The emergence hole of the mature parasite is either usually on any part of the aphid body or exclusively on the hind part.

Newly emerged parasites mature within a very short time and are soon able to mate and deposit eggs. The males emerge somewhat sooner than the females. Mating takes only a few seconds. The development time depends on temperature, and is usually from two to a few weeks; under normal conditions, it is about two weeks.

The mature aphidiids are mainly active on warm, sunny days and mostly in the late afternoon. Under favourable conditions, aphidiids live two to three weeks and more. Usually, there are slightly more females than males. The mature aphidiids consume the honey dew produced by the aphids.

The egg deposition is very characteristic. The female examines the aphid using her antennae; then she rises up on her legs, bends her abdomen, pushes it between her legs and rapidly stings the aphid with her ovipositor and deposits the egg. The eggs may be deposited in all of the development stages of the aphids but mainly the lower development stages are attacked. Depending on the number and activities of the female parasitoids, the dead parasitized aphids may occur individually or in whole groups.

Aphidiids exhibit bisexual propagation: females emerge from fertilized eggs and males from unfertilized eggs. Parthenogenesis is relatively rare.

The fertility of the females is very variable and may be up to a few hundred eggs. Some of the eggs are already mature at the time of emergence of the parasite; other eggs mature during the life of the female.

Parasitism of the aphids is connected with the successive impoverishment of the nutrition of the host which ends in the attack of the vital organs and the consequent death of the aphid. Aphids attacked by the parasite during their lower development stages die prior to reaching maturity; those attacked during the higher development stages mature and may also produce a smaller number of progeny.

Parasitism also partly changes the behaviour of the aphids in the colony. The lower development stages of the parasite within the aphid are not obvious from the outside. As the larva of the parasite grows, the aphid becomes slower in its movements and reactions. Some parasitized aphids may leave the colony before their death and move to other microbiotopes so that mummies of the aphids may also sometimes be found outside the colony. An important role is played here by the seasonal adaptation of the parasitoids. The departure of

the parasitized aphids is a sign of a state of rest (diapause) in the development of the next generation.

Aphidiids are widely distributed throughout the world, mainly, of course, in the zone of mild to subtropical climate of the northern hemisphere. Their individual faunal complexes correspond largely with the main plant associations. In forests, the aphidiids are very sharply divided by their connection with aphids living either on coniferous trees or on broad-leaved trees apart from those species typical for undergrowth.

Aphidiids are distributed over larger distances passively by air streams and over shorter distances by flying or walking. To a certain extent, aphidiids are also passively distributed as eggs or larvae in the bodies of parasitized winged aphids. This means of distribution depends on the species since the majority of parasitoids prefer the lower development stages of aphids. The parasitized aphid is killed prior to reaching maturity and the development of the wings.

Their seasonal occurrence is dependent on that of their hosts. Very often, various species of aphidiids occur during the whole growing season; in some cases, they are very closely adapted to the life cycle of the hosts (diapause). Aphidiids overwinter as mature larvae or prepupae within the mummy.

Aphidiids are specialized in that their nutrition is only linked with aphids but they are differentiated by the further specialization of their taxonomic relationship with, or life cycle of, the host. Monophagy seldom occurs; generally they specialize on some species or genera of aphids of a certain taxonomic group. With oligophagous species of parasitoids, not all of the host species are equivalent and some of them are preferred more than others. For this reason, we differentiate between the main and alternative hosts.

The range of parasitoids bound to individual species, genera or groups of aphids is very varied and comprises a number of differently specialized parasitoids. In general, groups of aphids which are further in their development have a narrower range of parasitoids which are, of course, more specialized.

Likewise, groups which are less advanced in their development have a very wide range of parasitoids. Within the range of aphids, we differentiate between the main or dominant species of parasitoid and the secondary or less important species. The mutual relationships between these species is totally stable over a wide region but, in individual collections or samples, a certain variability exists. The relative abundance of parasitoids is dependent on the host species present. Any further intraspecific differentiation has, of course, yet to be proved by laboratory experiments and special investigations. At the present time, a great deal of attention is being given to this subject.

The relationship between aphidiids and the ants which care and protect some species of aphids is very special. In general, ants tolerate the parasitoids in a colony; in some cases, they feed and care for them even though the activity of the parasitoids leads to a reduction in the number, and even to the full extermination, of the aphids in the colony (cleptoparasitism). This relationship between ants and parasitoids is important and different with that of the predators which are directly attacked, repelled or killed by the ants.

The activity of parasitoids reduces the number of aphids in the population. This is mostly the result of direct parasitization but the activity of the parasitoids also disturbs and the rest the aphids in the colony. The aphids spread and fall to the ground where they are often destroyed by other groups of natural enemies.

The effectiveness of parasitoids as population regulators changes according to the species of aphid or parasitoid and is, in individual years, within the whole complex of the natural enemies of aphids (i.e., predators, parasitoids and pathogens). The influence of parasites on the reduction of an aphid population is often very inconspicuous and for this reason escapes attention. However, it contributes to the natural reduction of aphids, which do not then reach a harmful level.

Ecological pest management mainly requires the exact determination of the nutritional relationships in a given biocoenosis. These relationships between aphids and parasitoids may range from being coincident to principally different since parasitoids may also attack some species of aphids on different plants. Situations arise where the fauna of aphids on various tree species is quite isolated, whereas the nutritional relationships (range of hosts) of parasitoids are mutually connected. Knowledge of these relationships is necessary not only for the biocoenosis of forests but also for the artificial biocoenoses of parks, residential towns and recultivation land in a landscape. In many of these places, plants are exposed to the impact of adverse effects of the environment and are more liable to attacks by pests (aphids) which in just these cases achieve high population levels. In these situations, natural regulars of aphid populations, including parasitoids, are applied.

From the whole group of aphidiids, which is relatively rich in species, we list only six species which will give some general information: *Trioxys pallidus* (HAL) (Tab. 47, Figs. a—c), *Aphidius setiger* MACK, (Tab. 47, Figs. d—e), *Praon flavinode* (HAL) (Tab. 47, Figs. f—g), *Ephedrus prociphili* STARÝ (Tab. 48, Figs. a—b), *A. schimitscheki* STARÝ (Tab. 48, Figs. c—f) and *Pauesia laricis* HALIDAY (Tab. 48, Figs. g—h). Under the conditions of Central Europe, the role of aphid parasitoids in forest biocoenoses is not of key importance. Only a few species of aphids are important pests of forest trees. The situation is different in other regions where parasitoids are applied according to a programme of integrated pest management. Interest in the study of this group of insects and its use is steadily increasing.

# TACHINID-FLIES

The tachinid-flies (*Larvaevoridae*) together with the gad-flies and the family of blow-flies presently belong to the superfamily *Thecostomata* of the *Diptera* order. The tachinid-flies are larger than, but similar in appearance to the blow-flies; they are mostly grey, or grey-blue to black coloured with standing hairs over the whole body. This hairiness of the individual parts of the body is the most important characteristic used in the

identification of individual species, which are otherwise very similar.

Tachinid-flies are very important and greatly useful in biological forest pest control since they are important parasitoids of the caterpillars and pupae of the nun moth, gypsy moth, browntail moth, pine beauty and loopers and also of larvae of saw-flies. Among the groups of *Larvaevoridae* which are lower down the development scale, where blow-flies are very numerous, parasitism is not so pronounced since their larvae mainly live saprophagously. Only some species (*Sarcophaga*) have a pronounced transition towards parasitism. Most species of true Larvaevoridae are oviparous i.e., the deposited eggs contain fully developed larvae (e.g., *Ernestia rudis* FALL.) which emerge immediately after egg deposition. How the eggs are deposited is important: either the females lay their eggs directly onto the skin or the hairs on the body of the host (caterpillars) or they deposit them on live plants in the environment, most frequently on the border of the feeding area. The form of the eggs and their number are adapted to suit the deposition. They are either loaf-like and very numerous (*Parasetigena* and *Exorista* spp.) or stalk-like on caterpillar hairs (a common phenomenon mainly of the very fertile females of the genera *Phryxe* and *Ernestia*).

This book lists only some of the most important species of *Larvaevoridae* which at the outbreak of pests, mainly of the nun moth and pine beauty, have a decisive role in the considerable reduction of the populations of these pests without the need for the use of chemicals. It should be mentioned that the unsuitable use of pesticides can reduce the importance of *Larvaevoridae* since they are more sensitive to chemicals than the pests. For this reason, it is of immense importance in integrated forest protection to use pesticides very carefully, and only after an investigation of the number of *Larvaevoridae* in the endangered region.

An especially important species is *Parasetigena agilis* R.D. (Tab. 49, Figs. a—f), a parasitoid of the nun moth. This species can destroy up to 80 % of the caterpillars and pupae although it has only one generation per year. Of similar importance is *Exorista larvarum* L. which parasitizes on more than 50 species of caterpillars, mainly those of lymantrids, lasiocampids and moths. *Exorista larvarum* L. has two generations each year (Tab. 49, Figs. g—i).

*Ernestia rudis* FALL. (Tab. 50, Figs. a—e) parasitizes mainly caterpillars of the pine beauty and pine moth. The female deposits only one egg in the host but lays up to 900 eggs in total. During the outbreak of the pine beauty in Slovakia in the 1930's, this fly reduced the pest population by 60 %. The same host is parasitized by the related species *Parasetigena agilis* R.D., which often deposits eggs by the beginning of May, the earliest of all of the *Larvaevoridae* species. During an outbreak of the oak leaf roller in warmer oak forests, besides other parasitoids, three other species of *Larvaevoridae* also had an important role: *Bessa selecta* MG., *Actia crasicornis* MG. and *A. pilipennis* FALL. The population level of the tortricid was rapidly reduced and the pest was already rare by the next year. The tachinid-fly *Agria affinis* FALL. is also an important parasitoid of nun moth caterpillars (Tab. 50, Figs. f—i).

The number of tachinid-fly larvae in the body of the host varies. With smaller species, for instance, with the larvae of the saw-flies, only one larva is present and, at the end, this is also somewhat larger than the body of the host. To the contrary, in the large caterpillars of sphinx moths and lasiocampids, the number of tachinid larvae is larger and it is in often the tens.

The emergence of the larvae of tachinid-flies depends, as with all insects on the temperature of the environment. In the body of the host, larvae of the tachinids, white as ivory, settle mainly in non-vital organs so that they do not directly endanger the life of the host. The tissue of these organs is decomposed into a thin mash which the tachinids consume. Many researchers consider this to be evidence that tachinid-flies developed originally from saprophagous forms. Either the whole of the tachinid-fly larvae is hidden in the body of the host and the necessary atmospheric oxygen is received osmotically or, in the early stages, only the front part of the larval body is hidden in a specially prepared funnel. In the latter case, the larva penetrates the body of the host later and mainly consumes the fatty tissues. The development of tachinid larvae ends as a rule in the third week of June. The full-grown larvae either leave the body of the host and fall to the ground, where they pupate in shallow litter, or they remain in the host body if the parasitized caterpillars have reached pupation. Most puparia overwinter in the litter of trees near to the feeding area. Tachinid-fly imagines emerge easily from the pupae, and in the parasitized pupae the membranes between the segments are softened. If there is more than one imagine in a pupa, they crawl out, as a rule, through one opening. In a pupa of *Sphinx pinastri* L. up to 18 puparia were found.

Parasitized caterpillars are obvious due to not only their slower movement but also mainly their lack of interest in food. In strong winds, these caterpillars easily fall to the ground and, as a rule, do not climb the stem into the tree crowns.

The economic importance of tachinid-flies in biological forest pest control is large and was soon realized, mainly from outbreaks of the nun moth and also of other pests. Tachinid-flies often determine the further development of pests by reducing their population activities to the lowest level. We find adult tachinid-flies in forests from spring to autumn but mostly during the summer months. In warm sunny weather they like to stay on the flowers of *Daucaceae* since, on the open nectaria of these plants, they find numerous representatives of other insects together, which produce sufficient honey dew to allow the maturation of their ovaria. Often in the afternoon, tachinid-flies sit on exposed tree stems and on stones where they mate and, after copulation, fly in the tree crowns and search for caterpillars on which they deposit eggs. It has been proved many times that tachinid-flies which prefer *Daucaceae* can be used for pest control. The forester can use wasteland to grow hogweed cowparsnip (*Heracleum spondylium* L.), bishops goutweed (*Aegopodium podagraria* L.), European waterhemlock (*Cicuta virosa* L.), *Labanotis montana* CR., and *Bupleurum temulum* L. etc., which are all abundant species in Central Europe and which make modest demands on the environment. These plants serve as attractants for the flies.

## Formica rufa L.

a — worker; b — female; c — male

This is a typical representative of forest ants of the genus *Formica* and is a common ant of our forests. Workers of this species are 4 to 9 mm long and polymorphic. Their colouring is characteristic: the rear half of the head, the abdomen and the spots on the pronotum and mesonotum of the thorax are deep black; the rest of the body is rusty red. The rear border of the head is not hairy; on the lower side of the head there are some standing hairs. There are 10 to 50 hairs on the pronotum. The females are similarly coloured; the thorax and abdomen are bright; the first segment of the abdomen is not hairy. They are, like the black males, 9 to 11 mm long.

The association of *F. rufa* L. may be monogynous or polygynous. Monogynous nests are always isolated and the ants of such a nest are very intolerant of other nests of the same species. These monogynous nests are inhabited by up to 500 000 workers, which are more robust than the polygynous workers. The mounds are higher than the polygynous mounds, steep, composed of very rough material and most frequently situated in shaded places with rich vegetation. The system of pathways to and from the mound is nearly invisible. Polygynous nests often form less polykalic colonies; the ants are tolerant and usually smaller. The flatter mounds are formed more on less shaded sites and are inhabited by more than 500 000 workers. The construction material for the nests is usually finer and the pathway systems more pronounced. Nests of both types of associations are frequently supported on rotten stumps or root swellings of trees or on other solid types of support.

This ant is a species of mixed and coniferous forests of lowlands and foothills. In Central European mountains, it ascends up to a height of 1000 m. *F. rufa* L. is one of the most frequently occurring ants in the whole of Europe. In the Caucasus, it is rare and, further to the east, it is replaced by other species. It does not occur to the east of the Baical Lake.

a

b

c

## Formica (Serviformica) fusca L.

a — worker; b — female; c — male

This frequently occurring species is typical of the whole subgenus *Serviformica*. The worker is completely black dull and ranges in size from 4.5 to 7.5 mm. The pronotum is bald (without standing hairs) and, in this way it is obviously different from the related species *F. lemani* BOND., the worker of which has standing hairs on the pronotum. The females are 7 to 10 mm long. The nuptial flight occurs from June to September according to the prevailing conditions. The society of this ant is monogynous or weakly polygynous. However a swarm inhabits only one nest: polykalic colonies are not erected. The earth nests are, as a rule, under stones, wood or moss, or in grass clusters or small clay mounds. The nests are frequently found in decayed stubs, in rotten wood and beneath bark. The colonies are never numerous, but include some hundreds of females. The may be found on nearly all open places, in half-shade and in the middle of dense stands. These ants are also distributed on wet lands and on rocky localities.

This species occupies all suitable biotopes, from low-lands to mountains up to an altitude of 1000 m above sea level. From 500 m above sea level, they occur in cooler and more humid biotopes and are successively replaced by the related species *F. lemani* BOND. *Formica fusca* L. is distributed throughout the whole of Europe and the whole northern part of the Palaearctic region. It also inhabits non-arctic regions and, besides this, it has been introduced to northern Africa, the Canary Islands and Sumatra. The stalk (petiole) is the transformed second abdominal segment which runs above into the scale, the form of which is a useful identification characteristic.

Grass Ant — *Formica pratensis* RATZ.

This species which is not included in the narrower group of forest ants of *Formica rufa* L has, as a rule, relatively robust workers which are 5 to 9 mm long with very pronounced colouring. The head is a blackcolour; the spots on the thorax and abdomen are very dark and dull. Other surfaces of the body are a fresh rusty red. The black spots on the pronotum and mesonotum of the thorax are large and have sharply contrasting borders. The whole body and head are densely covered with long standing hairs.

The females are 9 to 11 mm long, bald and very dully coloured. The males are completely black, dull and 9 to 11 mm long. The mating flight occurs in May and June; some observations indicate a second mating flight on warm sites in the second half of July.

Their associations are monogynous and polygynous. The monogynous nests are found on open sites in indi-vidual flat mounds, whereas polygynous nests occur on the borders of light stands where they form smaller pol-ykalic colonies. Both forms tolerate relatively high surrounding vegetation but this must not shade their nests. The nests are mainly flat broad mounds of rough construction material, usually blades of grass, small clods of soil and stones. The nests have no fixed support and are often depressed in the centre in springtime. Although most of these nests do not exceed a height of 50 cm, nests of a height of 1 m may, nevertheless, be found mainly of the polygynous form.

This species inhabits all suitable steppe, forest steppe and forest biotopes of lowlands and hills. It occurs very frequently on limestone. In Central Europe, it ascends mountains up to an elevation of about 800 m above sea level. It occurs over the whole of Europe and Siberia to the Pacific Ocean coast.

*Formica polyctena* FÖRST.

a— worker; b — female; c — male; below — mounds

This species, which is economically the most important of the forest ants, has smaller workers about 4 to 8 mm long. Their colour is, as a rule, lighter, since their black pigmentation is not so strong but browner and the red parts of the body are a more rusty yellow. The whole body has very few hairs; there are two standing hairs at the most on the pronotum. Sexually mature individuals are nearly identical to the winged forest ants (*F. rufa* L). The mating flight occurs from May to July according to the elevation of the site above sea level and other conditions.

The swarms are very polygynous: up to 500 females live in the nests. Individual nests often number more than one million workers and reach huge sizes. Nests with a height of 100 to 200 cm and a diameter at the base of about 5 m are also known. In polykalic colonies, often tens of nests are connected. The form of the nest is adapted both to the site conditions and to the available construction material. This material is, as a rule, fine. The nests are supported by stumps or heaps of old slash. They require very sparse surrounding vegetation. The system of pathways to the nests is very long and obvious.

The distribution of this species is similar to that of the species *F. rufa* L, with which it is confused. In Central Europe, it is found in mountainous regions and may also be seen at 1 300 m above sea level. It is well adapted to life in huge pure stands of conifers, not only in foothills but also in lowlands and on sand.

Its economic importance is due to its reproductive ability, large numbers of individuals, agressiveness and ability to divide swarms to form new colonies, etc.

## Formica lugubris ZETT.

a — worker; b — female; c — male; below — typical mound

Workers of this species are pronouncedly hairy over the whole body and head, where standing hairs form small wreaths round the whole rear border. Numerous long hairs also exist on the sides of the thorax and on the pronotum and mesonotum. The black spots on the thorax are diffuse with indistinct borders. The workers are fairly robust and 5 to 9 mm long. The females grow up to 11 mm long and have a very bright, pitch black abdomen. The front vertical portion of their first abdominal segment is covered by standing hairs. The mating flight occurs during the period from the end of June to mid-August.

The swarms of this ant are always polygynous with large numbers of fertile females. The nests are very heavily occupied and often form strong polykalic colonies. The largest known colony (a federation of colonies) in the Swiss Jura mountains has more than 12 000 nests mutually connected by more than 100 km of ant path-ways. The system of pathways is always rich and obvious. The nests are made from rougher material and are, as a rule, about 1 m high and of a conical form. Only on sunny sites are the nests lower and oval — shaped. The nests are mainly found in mountain spruce forests with thin or no ground vegetation cover.

The ant, *F. lugubris* ZETT., is a northern species and its continuous distribution area forms a narrow belt from Scandinavia, north above Moscow to Japan. In Western and Central Europe, it inhabits the mountainous regions of the Pyrenees, Appenines and Alps. In Czechoslovakia this species is known from the Bohemian forest, Bohemian Moravian upland and the Jeseníky mountains. A very close relative, the boreal species *Formica aquilonia* YARROW is known from the Alps, Britain and Scandinavia. It was also recently found in Czechoslovakia in the region of the Novohradské hory mountains.

*Formica truncorum* F.

Although this ant belongs to the genus *Formica*, it is not included in the narrow group of *Formica rufa* L. Its morphology and way of life differ somewhat and there have been frequent discussions concerning the classification of this interesting species into an independent, newly-formed subgenus.

The workers are 5 to 9 mm long, with very dense, long, lightly coloured hairs. The black colour is very reduced so that the whole head, thorax, middle body and front part of the first segment of the abdomen are clearly rusty red. The females are 8 to 11 mm long and identically coloured but the black colour of their abdomens is dull and silvery. The mating flight occurs between July and August.

The swarms are mostly monogynous; small polykalic colonies of polygynous forms occur as exceptions. This species shows a very broad ecological amplitude, which permits it to occupy very different biotopes. The construction and arrangement of the nests are influenced by the environment. Although the nests are always on open sunny sites, their forms are very different. Most frequently we find the so-called stump nests, when mounds of needles are supported on a dry stump which is an integral part of the nest. The nest often covers the stump and takes on the known mound form. Ants of this species nest in hollow lying stems, in debris or heaps of stones, where gaps are filled with needles, in large clusters of grass, etc.

Although this ant is adapted to life in lowlands, hills and high mountains, it never occurs frequently. It inhabits the whole of Central and Northern Europe, Siberia, the Far East and the mountainous regions of Central Asia.

# Rapacious Ant *Formica (Raptiformica) sanguinea* LATR.
## *Formica (Coptoformica) exsecta* NYL.

a — *Formica sanguinea* LATR. worker; b — mandibles of worker; c — female; d — male; e — *Formica exsecta* NYL. worker

The species *Formica (Raptiformica) sanguinea* LATR. is the only representative of the subgenus *Raptiformica* in Europe. The workers are 5 to 9 mm long and red with a black abdomen. The whole body is very sparsely haired. A characteristic distinguishing feature is the deeply cut front border of the clypeus. This is common for larger females of the same colour and for black males. The mating flight begins in July or August. Monogynous swarms with some hundred workers are mainly found on open sunny sites in lowland and mountainous regions. The nests are constructed under stones, in stumps or in small mounds and are often inhabited together with assisting slave ants of two species, *F. fusca* L or *F. lemani* BOND, the pupae of which are stolen from neighbouring nests. However, the species also lives in pure swarms of its own members. It occurs frequently over the whole territory of Czechoslovakia, mainly on the borders of forests and on clear cut areas. It occurs from Europe to Japan.

*Formica (Coptoformica) exsecta* NYL. is a typical representative of the interesting subgenus *Coptoformica*. The workers are 4 to 7 mm long and similar in their colouring to forest ants. The head, thorax and abdomen, are a dull brown-black. A typical feature is the very strongly depressed hind border of the head and a similarly depressed upper edge to the scales of the middle body. These are also characteristic for the large 7 to 9.4 mm long two-coloured females and the completely black males.

Swarms of this species are strongly polygynous, numerous and form, as a rule, huge polykalic colonies, mainly on the borders of forest stands and pastures or on clear cut areas. One colony numbers some hundreds of individuals. It is distributed from Western Europe over the Caucasus to Altai and Japan. In Central Europe, a very closely related species, *F. (R.) pressilabris* NYL, is found. These species are often confused.

## Lasius niger L.
## Myrmica ruginodis NYL.

a — *Lasius niger* L. worker; b — male; c — female; d — *Myrmica ruginodis* NYL — worker; e — female; f — male

The worker of the most frequently occurring ant, *Lasius niger* L, is 2 to 5 mm long uniformly coloured brown-black to black. These workers are covered by small standing hairs over the whole body and mainly on the front tibiae and the scapes of the antennae. The females are much larger, 7 to 10 mm long, and brown-black. The abdomen is covered by a dense brown pubescence. The males are dark brown to black and only 3.5 to 5 mm long. The mating flight occurs between June and September.

The associations of this species are sufficiently strong but always monogynous. They mainly inhabit earth nests under stones and wood, in clay mounds, moss and peat bogs. The nests of these species may also often be found in decayed wood, under the bark of stumps and in the gaps in rocks. *L. niger* L is one of the most abundant ants. It inhabits the widest variety of biotopes from lowland to high mountains and is also found in towns. In forests it often occupies light forest stand borders and clear cut areas but also penetrates the enclosed, dark forest stands. Together with the species *Myrmica ruginodis* NYL, *L. niger* L also inhabits very moist and acid sites.

The workers of the species *M. ruginodis* NYL are 4 to 5.5 mm long, and rusty brown to black-brown with long, strong epinotial thorns. The surfaces of the body and thorax are strongly longitudinally wrinkled. The abdomen is very shiny. The females are a little larger, 5 to 6.5 mm long, and of the same colour. The black males achieve a lenght of only 5 to 5.5 mm. Reproductive swarming occurs between July and September. The swarms number some hundreds of workers and a few females. The choice of biotope and site as well as the nesting method is similar to that of the ant *L. niger* L. which often accompanies this species. However, *M. ruginodis* NYL. is found at higher elevations up to the mountain pine zone.

# Transection of the nests of *Formica truncorum* F. and *Formica rufa* L.

Left — nest of *Formica truncorum* F.; right — nest of *Formica rufa* L.

The ant *Formica truncorum* F. called the "stump ant" is in many languages due to the characteristic structure of its nest. In most cases, this ant occupies dry stumps or stems which have earlier been attacked by the ant *Camponotus ligniperda* LATR. or by other wood-destroying insects. The hollows and galleries in the wood form the basis of the ant nest. Simultaneously, the system of chambers and galleries in the soil under the nest is deepened. If the colony is strong (mainly polygynous swarms), the stump is, as a rule, fully covered and has the structure of a regular nesting mound.

The transection of the nest of the forest ant *Formica rufa* L. clearly shows the common structure of the needle mound of forest ants. The base is a funnel excavated in the soil. Around it there is an elevated earth wall constructed from the soil particles obtained during the excavation. The funnel is filled with rough material (twigs and branches up to 10 cm long) which forms the so-called inner cone of the nest. Most of the chambers in the nest are in the cone and in the funnel walls. Other chambers are constructed higher up in the so-called exterior cone consisting of finer material (needles) or, to the contrary, in the soil underneath the funnel where they reach depths of even more than 1 m in heavily occupied nests and under good soil conditions. A very important part of this construction is the earth wall which forms the support for the needle mound. All of the ant roads start and end on the nest wall and it is also where the division of influence spheres of individual partial swarms outside the nest begins.

## Picromerus bidens (L.)

a — adult; b — ventral side of body; c — larva; d — individual feeding on caterpillar of nun moth

This is a typical representative of the order *Rhynchota* from the family of the scale bugs *Pentatomidae*, which are entomophagous and entomosucking species (they suck the sap of insect bodies). It is dark brown, 10 to 12 mm long, with an oval, vaulted body. The shield is equipped with a sharp point on the sides, and the front, like the head, has large black spots, whereas the semi-elytra are finely dotted. The ventral side of the body is ochre yellow and sparsely dotted. The ambulatory legs make relatively rapid movement possible and also the flying ability of this species is good. The adults hibernate on dry spots, most often beneath the disconnected bark of old trees or in litter. They appear by early spring. This species does not occur frequently in forests but is more abundant in the shrub layer. At the mass outbreak of pests, mainly of the nun moth, it becomes more abundant. This species is useful since it feeds on caterpillars of various development stages, and also on the pupae, mainly of larger butterflies (e.g., the nun moth, pine beauty and pine moth) and often sucks on the larvae of saw-flies. The stung caterpillars defend themselves with jerky movements but they are soon paralysed and, when in the last instar, do not accept food and die early. Sometimes they reach pupation but no adults develop from the pupae. The saliva of this species is obviously toxic since the caterpillars do not move for a certain amount of time and loose interest in food immediately after being stung. The barrel-like eggs are typical in their shape and size for the whole family and are deposited on leaves and on the bark of stems in groups. The developed larvae remain together for a few days before they spread. The development, as in other *Pentatomidae* species, is heterometabolic (five nymphal stages). The larvae are not similar to the adults. Initially, for as long as they remain together, they search for freshly hatched caterpillars. This species has one generation per year in Central Europe.

## Carabus glabratus PAYK.    Calosoma sycophanta L.
## Pterostichus oblongopunctatus F.    Pterostichus burmeisteri HEER.

a — *Carabus glabratus* PAYK.; b — *Calosoma sycophanta* L.; c — larva; d — *Pterostichus oblongopunctatus* F.; e — *Pterostichus burmeisteri* HEER.

*Carabus glabratus* PAYK. is 2 to 3 cm long with small striking bright blue elytra, which, like the shield, have a fine grainy appearance and have light violet edges. Like all other *Carabidae,* it does not have membranous wings beneath the elytra; it does not fly but remains on the ground where it moves rapidly mainly at night and searches for caterpillars, small arthropods and slugs. As a carnivorous species, it is rightly considered to be useful like other larger ground beetles.

*Calasoma sycophanta* L. is 25 to 30 mm long; the shield and lower side of the body are metallic bluish—black. It has bright gold elytra which are longitudinally grooved and are golden red on the edges. These beetles emit a typical odour but not of the musk type as is often described. This species is not able to fly and so it is permanently bound to a suitable biotope but it moves about rapidly as it consumes a great deal of food daily. The larva is spindle-shaped, the upper part of the body is dark brown with a longitudinal lighter line and the lower side is lighter. It withstands hunger for a long period. Like the adults, the larva rapidly climbs trees, stems and branches and pursues its prey often in crown tops. It is mainly active at night from the beginning of June to the end of July.

*Pterostichus oblongopunctatus* F. is one of our most frequent species; it is 9—12 mm long, black and the upper side is slightly bright. There are some spots on the third interstitium of the elytra. Like all of the species of the genus *Pterostichus,* it is an important hunter mainly of caterpillars; this includes both the adults and the larvae. The adults also destroy many bark beetles on the stems of conifers at the time of their swarming.

*Pterostichus burmeisteri* HEER. is an important destructive species mainly of caterpillars. It is 12 to 15 mm long with bright copper brass elytra. It occurs frequently mainly in forests with moist humus and deep litter. It often hides itself beneath stones and stems and is very active at night.

## Calosoma inquisitor L.   Xylodrepa quadripunctata (L.)

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a — *Calosoma inquisitor* L; b — its bluish violet form; c — *Xylodrepa quadripunctata* (L); d — from a side view; e — larva

*Calosoma inquisitor* L is 15 to 22 mm long and dark brown; the elytra are longitudinally grooved and dotted with golden-green borders. The lower side of the body is metallic green. The shield and head are finely dotted with greenish edges. One frequent form (*f. coerulea* LETZN.) is a bluish-violet to bluish-black colour. This species is relatively widely distributed in Czechoslovakia and it is also abundant in some countries, mainly in lowland broad-leaved forests. Like its larva, the adult pursues caterpillars of pests at outbreaks mainly those of the green oak leaf roller, the geometrid moth *Erannis defolaria* CL, the browntail moth *Euproctis chrysorrhoea* L and the gypsy moth *Lymantria dispar* L This species, like *Calosoma sycophanta* L, is protected by law. It also occurs in gardens neighbouring forests and where pest control is neglected. In these forests it regularly destroys the caterpillars of *Erannis defoliaria* CL The larvae hatch from eggs deposited individually by the end

of May, become full-grown rapidly and pupate at the end of July.

*Xylodrepa quadripunctata* (L.) is 12 to 14 mm long; the body is broad and oval-shaped, and the lower side is bright black. The middle of the shield is black and the edges ochre-yellow. The wing covers are a similar yellow colour with two black spots on each of them. Like other carrion beetles, it flies excellently and is, therefore, not bound to a certain biotope. Unlike other carrion beetles, it is able to climb stems rapidly, often high into the crowns, like its black larva. This species is common in warmer regions and is an important predator of the caterpillars of the green oak leaf roller and of many other forest pests. During outbreaks of the green oak leaf roller, it prefers to feed on this species rather than on the decaying flesh of small vertebrates where it usually occurs together with other species of *Silphidae*.

*Quedius laevigatus* GYLL.   *Placusa tachyporoides* WALTL
*Nudobius lentus* GRAV.   *Metoponcus brevicornis* ER.

a — *Quedius laevigatus* GYLL.; b — *Placusa tachyporoides* WALTL.; c — *Nudobius lentus* GRAV. larva; d — adult; e — *Metoponcus brevicornis* ER.

*Quedius laevigatus* GYLL. is black, 6.5 to 8.5 mm long with slightly bright elytra, which are brown and have two rows of 4 — 5 spots on each of them. In mountain forests, this species occurs frequently beneath the bark of conifers. It is an outstanding enemy of bark beetles.

*Placusa tachyporoides* WALTL is one of the smallest representatives of *Staphylinidae*, it is 2 to 2.3 mm long and black with brown wing covers and legs. It lives the whole year in the tunnels of bark beetles, mainly those of the Norway spruce bark beetle *Ips typographus* L. and very often together with related and similar species. It is an outstanding external predator of bark beetles mainly on spruce stems with bark.

*Nudobius lentus* GRAV. is 7 to 8 mm long and black with brick-brown wing covers and legs. The antennae are red-brown, the head is finely dotted and the shield has two rows of 7 — 10 dots. The adult lives like its rapidly moving larva beneath the bark of conifers attacked by bark beetles. However, it is a relatively rare species.

*Metoponcus brevicornis* ER. is an elongated but very quick beetle, only 5.5 to 7.5 mm long, with a striking black elongated head which is finely dotted on the upper part. The wing covers are a dirty brown and finely dotted; the legs and antennae are rusty brown. It is an excellent pursuer of bark beetles mainly on silver fir and also sometimes on broad-leaved trees. It occurs seldomly but is more frequent during massive outbreaks of bark beetles.
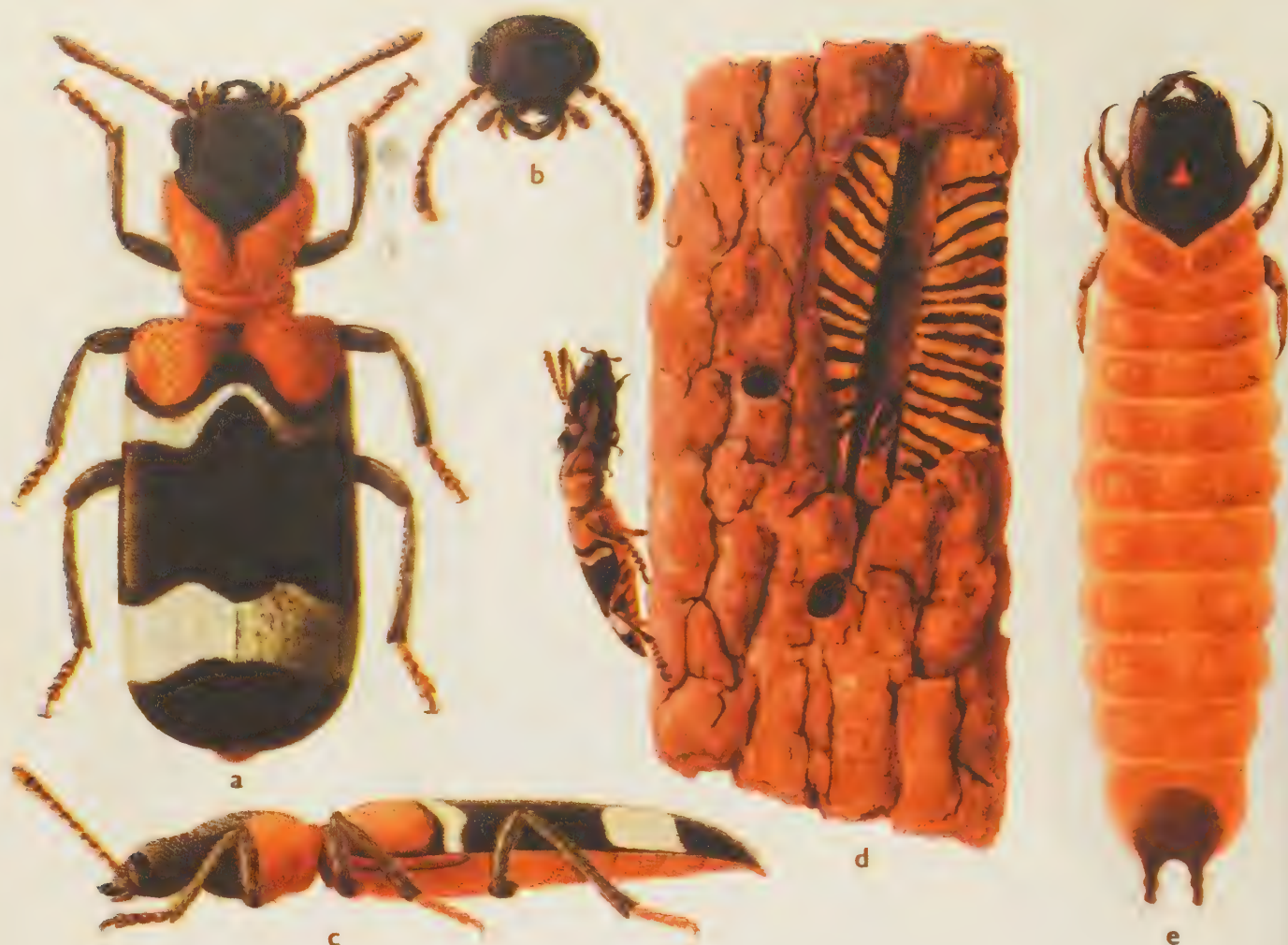
Predacious clerid beetle *Thanasimus formicarius* L.

a — adult; b — front view of head of adult; c — beetle front side view; d — beetle consuming bark beetle larva in galleries of bark beetle; e — larva

*Thanasimus formicarius* L. is 7 to 10 mm long; the shield and lower side of the body are a vivid red, the head and legs black, the wing covers red, white and black striped and the antennae club-shaped. The fore-tarsi are adapted for seizing bark beetles and the strong mandibles have two protrusions which look like tongs so that the cylindrical body of the bark beetle can be easily and firmly grasped. The body of this beetle is well adapted since it is flattened horizontally so that it can prowl among narrow crevices in bark, its favourite hideaway during bad weather. The full-grown larva is rose-yellow; the front part of its body is strongly chitinized and also, on the end of the body, there are thorny chitinous protrusions which allow it to move backwards rapidly in the galleries of bark beetles.

The adults seize bark beetles during swarming, climbing tree stems surprisingly rapidly. They grab the bark beetles most often from behind with their mighty mandibles and hold their prey with their forelegs. They rapidly remove the wing covers and shield of the prey and feed on the softer parts of its body. In this way, this predacious beetle captures some beetles, mostly females, every day. The larva is very alert during the pursuit of its prey. It initially consumes the eggs, then the hatched larvae and later the growing larvae and pupae of bark beetles.

Individuals of *T. formicarius* L. hatch early in spring from the pupae which overwinter under bark. They also hibernate. They have only one generation per year but, nevertheless, they are considered to be a very useful beetle, mainly during the years after there are large wind-breaks in Norway spruce stands, when the mass breeding of bark beetles, mainly the spruce bark beetle *Ips typographus* L., is a risk. This species is most active on warm spring days when the activity of the bark beetles attacking the stems is also at a maximum.

*Pseudoclerops mutillarius* (F.)    *Rhizophagus grandis* GYLL.    *Laemophloeus alternans* ER.

*Epuraea laeviuscula* (GYLL.)    *Laricobius erichsoni* ROS.    *Tillus elongatus* L.

a — *Pseudoclerops mutillarius* (F.); b — *Rhizophagus grandis* GYLL.; c — *Laemophloeus alternans* ER.; d — *Epuraea laeviuscula* GYLL.; e — *Laricobius erichsoni* ROS.; f — shield of this species; g — *Tillus elongatus* L., female; h — front part of male

*Pseudoclerops mutillarius* (F.) is our largest species of the family *Cleridae* and is 12 to 15 mm long. The wing covers are bright velvet, have a broad black stripe in the middle and have pronounced spots; the shield is black. The larvae live in the galleries of various wood-destroying insects in old oak trees.

*Rhizophagus grandis* GYLL. from the *Rhizophagidae* family is 4.5 to 5.5 mm long and bright chestnut-brown. A row of dots in related species which are similar in body form and size indicate the same kind of life. This species lives under the bark of conifers as an important enemy of the bark beetle *Dendroctonus micans* KUG.

*Laemophloeus alternans* ER. from the *Cucujidae* family is 2 to 2.5 mm long, and dull with bright spots on the head and shield. It lives in the galleries of the bark beetles *Pityogenes* and *Cryphalus* spp. beneath the bark of spruce and pines.

*Epuraea laeviuscula* (GYLL.) from the *Nitidulidae* family has a typically flat body. The adults are often found on flowers and fungi, and the larvae are important hunters of bark beetles, mainly of the lineate bark beetle *Xyloterus lineatus* OL. and *Hylurgops palliatus* GYLL.

*Laricobius erichsoni* ROS. from the *Derodontidae* family is a mountainous species. The species was considered to be rare and an important enemy not only of *Pseudococcinae* but also mainly of *Dreyfusia nordmannianae* ECKST.

*Tillus elongatus* L. belongs to the *Cleridae* family. Its wing covers are slightly hairy, black and bright. The antennae are comb-like; the segments are longer and sharper in the males. The species only occurs locally. The larva is an important hunter of the larvae of *Anobium, Pogonochaerus* and *Anthaxia* spp., and according to Professor Pfeffer, also of *Ptilinus pecticornis* L.

*Anatis ocellata* (L.)   *Coccinella septempunctata* L.

a — *Anatis ocellata* L. *adult* feeding on *Dreyfusia nordmannianae* ECK.; b,c — *adults of typical colour; d — eggs; e — Coccinella septempunctata* L; f — eggs; g — larva; h — pupa

*Anatis ocellata* (L) is the largest ladybird beetle in Central Europe. It is 8 to 10 mm long; the wing covers are red-brown with black dots with indistinct edges, which may vary considerably in shape and size and in colour to yellow-brown. The shield is always black with typical yellow-white markings. The end of the sutura of the wing covers has a shallow cut and is covered by fine hairs. The eggs are deposited individually on the lower side of needles or directly on bark. The adults often consume (also on broad-leaved trees) the soft eggs of *Geometridae* and leaf rollers and the hatched caterpilars of numerous species of butterflies.

*Coccinella septempunctata* L. is such a common species that it need not to be described and also because it varies little. The eggs are lemon-coloured, and are always deposited in small groups on the leaves and branches near colonies of aphids. The larvae are ash-grey and yellow-spotted; the body surface has numerous bumps covered with tough hairs. Each larva, during its lifetime, consumes at least 300 aphids. The numbers given in the literature are often exaggerated, even up to three times this quantity. The pupa is red-brown, with black spots, and always hangs fixed from the end of its abdomen to plants. The adults hibernate on dry spots, very often collectively. By the first warm days of spring, *Coccinellidae* individuals are attracted from their hiding places and they copulate immediately. The hatched larvae are very mobile and attack, as a rule, the first development stages of aphids; it this way they contribute to the consequent reduction in the numbers of the aphid population.

*Adalia bipunctata* L.    *Adalia conglomerata* L.    *Scymnus frontalis* F.
*Scymnus nigrinus* KUGEL.    *Scymnus abietis* PAYK.    *Scymnus punctillum* WEISE
*Chilocorus bipustulatus* L.    *Chilocorus renipustulatus* (SCRIBA)    *Exochomus quadri-pustulatus* (L.)
*Propylaea quatuordecimpunctata* (L.)    *Hyperaspis campestris* L.    *Coccinula quatu-ordecimpustulata* L.

a—f — *Adalia bipunctata* L., its larvae and pupa; g — *A. conglomerata* L.; h — *Scymnus frontalis* F.; i — *S. nigrinus* KUGEL.; j — *S. abietis* PAYK.; k — *S. punctillum* WEISE.; l — *Chilocorus bipustulatus* L.; m — *Ch. renipustulatus* (SCRIBA); n — *Exochomus quadri-pustulatus* (L.); o — larva; p — pupa; r—t — *Propylaea quatuordecimpunctata* (L.); u — *Hyperaspis campestris* L.; v — *Coccinu-la quatuordecimpustulata* L.

*Adalia bipunctata* L. is the most frequent species of la-dybird beetles; it is 3.5 to 5.5 mm long and very variable in colour.

*Adalia conglomerata* L. is 3 to 4.5 mm long. It is a mountainous species, is distributed here and there in Czechoslovakia.

*Scymnus frontalis* F. is 2.5 mm long and black with wing covers which are covered in dense hairs. The head of the male is red-brown and that of the female black.

*Scymnus nigrinus* KUGEL. is 2 to 2.8 mm long; the black wing covers are often metallic and bright. This species occurs frequently on pines.

*Scymnus abietis* PAYK. is the same size as the previous species but the whole of the body is red-brown. It is a frequent species on spruce, mainly in the top parts of the trees.

*Scymnus punctillum* WEISE is the smallest species of ladybird beetles. It is the latest occurring of all of the

species in its natural environment and does not appear until the end of summer.

All of the species are mainly important enemies of shield bugs. The smallest species, *Scymnus punctillum* WEISE, and its larva feed on various species of *Tetrany-chidae* and on the larvae of thripses.

*Chilocorus bipustulatus* L. is 3 to 5 mm long, and like *Ch. renipustulatus* (SCRIBA.) and *Exochomus quadripustu-latus* (L.), frequently occurs on conifers and broad-leaved trees and is an important feeder on shield bugs. The spiny exuviae hide the pupa.

*Propylaea quatuordecimpunctata* (L.) is not only one of our most frequent species.

*Hyperaspis campestris* L. is 4.2 mm long. The wing covers are red-brown and the two red-yellow dots are often absent.

*Coccinula quatuordecimpustulata* L. is 3 to 4 mm long and is a very frequent inhabitant of forest borders.

*Raphidia flavipes* STEIN
*Drepanopteryx phalaenoides* (L.)
*Semidalis aleyrodiformis* (STEPH.)

a — *Raphidia flavipes* STEIN female; b — male; c — larva; g — mandibles of larva; e — egg; f — *Drepanopteryx phalaenoides* (L.); g — web of its larva; h — *Semidalis aleyrodiformis* (STEPH.); i — egg; j — larva

*Raphidia flavipes* STEIN is our most frequent species. The female has a red-brown body with white markings on the abdomen and yellow legs. The wings are glass-like with a characteristic venation; on both pairs of wings there are two coloured pterostigma the inside of which is dark brown and the exterior yellowish. The wing span is 20 to 28 mm. When at rest, the wings of *Raphidia* spp. assemble roof-like over the body. The larvae, although they are long, are very mobile and, in the galleries of insects beneath bark, they can move forwards and backwards at the same speed. They are equipped with strong mandibles.

*Drepanopteryx phalaenoides* (L.) is one of the largest species of its family. It is rusty brown, densely hairy on the body and has broad, falcon-like wings, the shape and venation of which are similar to that of a dry leaf. The longitudinal transversals on the wings are dense and hairy. The wing span is 25 to 34 mm. This species occurs in broad-leaved and coniferous forests, parks and fruit-treee gardens. When disturbed, it looks like it is dead with the wings assembled roof-like over the abdomen. The larvae feed on aphids; the full-grown ones prepare an orange-yellow web, which is double-layered; the inner layer is made from harder fibres and the exterior layer from looser light yellow fibres.

*Semidalis aleyrodiformis* (STEPH.) is typical of the larger species of its family. The body and wings are covered with a wax-like dust. The span of the wings, both pairs of which have a simple and almost identical system of veins, is 7 to 8 mm. The imagines often occur in large quantities in broad-leaved forests, and also in parks and orchards, always on trees and shrubs. The eggs are oval with a typical microstructure on the surface. The larva is grey-black with white spots. It feeds on the first instars of aphids, and mites and their eggs.

*Wesmaelius quadrifasciatus* (REUT.)    *Hemerobius micans* OLIV.
*Hemerobius atrifrons* MC LACH.    *Hemerobius pini* (STEPH).    *Hemerobius humulinus* L.

a — *Wesmaelius quadrifasciatus* REUT.; b — larva; c — *Hemerobius micans* OLIV.; d — larva; e — *Hemerobius atrifrons* MC LACH.;
f — front view of its head; g — *Hemerobius pini* (STEPH.); h — larva; i — *Hemerobius humulinus* L.; j — larva

*Wesmaelius quadrifasciatus* (REUT.) belongs to the largest species of brown lacewings. It has broad wings and is grey to black with yellow-brown markings on the dorsal side of the body; the wings have hairy veins and grey-brown dots. The radial vein has four branches. The wing span is 19 to 26 mm. The imagines and larvae of this species occur in coniferous forests mainly in the moist and colder biotopes from the lowlands to the mountains.

*Hemerobius micans* OLIV. is a yellow-brown to grey-brown colour with yellow frons. The imagines and larvae occur on broad-leaved trees and shrubs. It occurs most frequently on beech. It is one of our most common species.

*Hemerobius atrifrons* MC LACH. is a brown-black to black-coloured species of smaller size. The forewings have dark stripes and spots. The frons is typically bright and black. The wing span is 13 to 17 mm. The imagines and larvae are typical for larch forest stands although we can also find them on other coniferous trees.

*Hemerobius pini* (STEPH.) has a light band on the dorsal part of the body; the wings are brown with dark brown spots connected with stripes. The frons is bright and brown. The wing span is 13 to 17 mm. The imago and larva live in coniferous forests from lowlands to mountains. It is one of the most frequent and most widely distributed species.

*Hemerobius humulinus* L. is a light brown species; the sides of the dorsal part of the thorax are brown. The wings have brown shadows; on the forewings there is a dark transversal which is a typical characteristic of this species. The frons is light brown or yellow. The wing span is 15 to 19 mm. The imagines and larvae live in a wide variety of coniferous and broad-leaved biotopes on trees and shrubs, and also in parks and orchards as well as in gardens.

*Chrysopa septempunctata* WESM.    *Nineta pallida* (SCHNEIDER)
*Chrysoperla carnea* (STEPH.)    *Chrysopa dorsalis* BURM.
*Chrysopa perla* (L.)    *Anisochrysa prasina* (BURM.)

a — *Chrysopa septempunctata* WESM.; b — *Nineta pallida* (SCHNEIDER); c — *Chrysoperla carnea* (STEPH.); d — larva; e — cocoon; f — cocoon after hatching of imagines; g — *Chrysopa dorsalis* BURM.; h — *Chrysopa perla* (L.); i — *Anisochrysa prasina* (BURM.); j — larva of this species with remains of parasitized aphids on dorsal side

*Chrysopa septempunctata* WESM. is a large, dark green species with a black dot on the head between the antennae and the occiput. The wing span is 30 to 40 mm. It generally lives on broad-leaved trees and shrubs in forests and also often in town orchards and gardens.

*Nineta pallida* (SCHNEIDER) belongs to the group of large species of *Chrysopidae* and is separated into an independent genus (*Nineta*). The imagines are dark green with two typical stripes on the dorsal side of the body. The wings are opalescent with a span of 38 to 48 mm. The imagines and larvae are typical for coniferous forests from lowland to mountainous spruce forests.

*Chrysoperla carnea* (STEPH.) is one of the most common and best known of our *Chrysopidae* species. It is light green coloured, with a longitudinal yellow dorsal stripe in summer and red dots in winter.

*Chrysopa dorsalis* BURM. is dark green-coloured with typical black markings on the thorax and abdomen. On the head between the antennae there is a cross-shaped marking. The wing span is 22 to 28 mm. It is not a frequent species but is typical for Scots pine forests.

*Chrysopa perla* (L.) is a dark to bluish-green species with black markings on the body. On the head, there is a typical black spot between the antennae and the vein on the wings is green. The dorsal side of the male's body is green and that of the female green with black spots in rows along the body axis. The wing span is 26 to 32 mm. It is our second most common green lacewing on broad-leaved trees and shrubs and also on conifers.

*Anisochrysa prasina* (BURM.) is a green species with black spots on the body. It has a black spot between the antennae, and also similar spots on the prothorax. The underside of the abdomen is green. The wing span is 25 to 34 mm. The species lives in broad-leaved forests but also in areas with shrubs. The larvae carry the remains of the exhausted prey on their dorsum.

## Laphria flava L.    Lonchaea seitneri HENDEL

a — *Laphria flava* L.; b — side view of head; c — front view of head; d — waiting for prey; e — *Lonchaea seitneri* HENDEL;
f — larva; g — puparium; h — larva and pupa in the cradles of bark beetles

*Laphria flava* L is 16 to 22 mm long with a robust thorax and abdomen, which are a strong yellow-brown colour and hairy. The large wings which are attached to the thorax make rapid flight possible. The legs are robust, densely hairy and end in strong claws which are used for catching the prey. The eyes are strikingly big. When waiting for insects, *L. flava* L sits on stones, the edges of stumps or tree stems. It hunts flies, weevils, bark beetles, butterflies and other insects while in flight. The female deposits the eggs on old tree stumps. Some authors report that the larvae consume decaying bark while, according to others, they pursue wood-destroy-

ing insects beneath the bark. The pupa has a wreath of spines on the abdominal segments in a similar arrangement to that of the pupae of *Sesiidae*. The life cycle of the larvae of *L. flava* L has not been fully established and further studies are needed.

*Lonchaea seitneri* HENDEL is 5 mm long and blue-grey, with wings which are yellow at the root. This species deposits eggs using its tough ovipositor in the mother galleries of bark beetles, where the hatched larvae consume the larvae and pupae of bark beetles and also pupate at the feeding place. The hatched adults penetrate outwards through the bore holes.

*Scaeva pyrastri* (L.)    *Epistrophe balteata* DEG.    *Dasysyrphus tricinctus* FALL.

a — *Scaeva pyrastri* (L.); b — head from side view; c — head from front view; d — larva; e — puparium; f — puparium after hatching; g — *Epistrophe balteata* DEG.; h—i — larva; j — puparium; k — *Dasysyrphus tricinctus* FALL.

*Scaeva pyrastri* (L.) is 14 mm long. The eyes are finely haired. The larva is yellow-green or yellow (depending on the species of aphids it consumes) and the puparium is grey-green. This species occurs frequently in broad-leaved forests.

*Epistrophe balteata* DEG. is the most frequently occurring species. The whitish larva is 7 to 9 mm long and the puparium has little black bows. The stigmata are brown with black-bordered ostia. Fig. i shows the change in body shape of the larva.

*Dasysyrphus tricinctus* FALL. is distributed over the whole of Europe and is abundant from the beginning of May to the end of September.

The size of the three full-grown species of flower-flies shown ranges from 10 to 14 mm in length. The colour of the larvae is also considerably variable and dependent on the species of aphids consumed. The species *E. balteata* DEG. can be white, dark grey, dark green or green-brown in colour.

### Syrphus ribesii L.  Megasyrphus annulipes ZETT.  Posthosyrphus luniger MEIG.
### Sphaerophoria scripta L.  Melanostoma mellinum L.  Heringia virens F.

a — *Syrphus ribesii* L; b — larva; c — *Megasyrphus annulipes* ZETT.; d — *Posthosyrphus luniger* MEIG.; e — larva; f—g — *Melanostoma mellinum* L; h — head of male from front and side views; i — *Heringia virens* F.; j—k — *Sphaerophoria scripta* L.; l — head...

*Syrphus ribesii* L is 11 mm long. It is abundant everywhere in Czechoslovakia. It flies from April to the end of September. The colour of the larvae is very varied. In the colonies of the currant aphid, the larvae are ochreyellow. It is an important enemy of *Chermes viridis* RATZ. The larvae are olive-green with a chancre-like cover over the body.

*Megasyrphus annulipes* ZETT. is also abundant in Central Europe. It may be easily confused with the species *Posthosyrphus luniger* MEIG. (Fig. d).

Both species are very useful because they have more than one generation per year so that the larvae destroy a large quantity of aphids.

*Sphaerophoria scripta* L is outstanding due to the different colours and forms of the sexes. It is very abundant on the borders of pine forests from May to the end of September. It is a xerophilous species.

*Melanostoma mellinum* L. is a smaller species and less striking in colour. It occurs frequently in damper areas. Its larvae consume not only aphids but also caterpillars of the first instars for as long as these stay together. This species is found everywhere.

*Heringia virens* F. is one of to the smallest species and is only 6 mm long. It is greenish in colour. The larva consumes root aphids. It flies from May to August. It seldom occurs in Czechoslovakia.
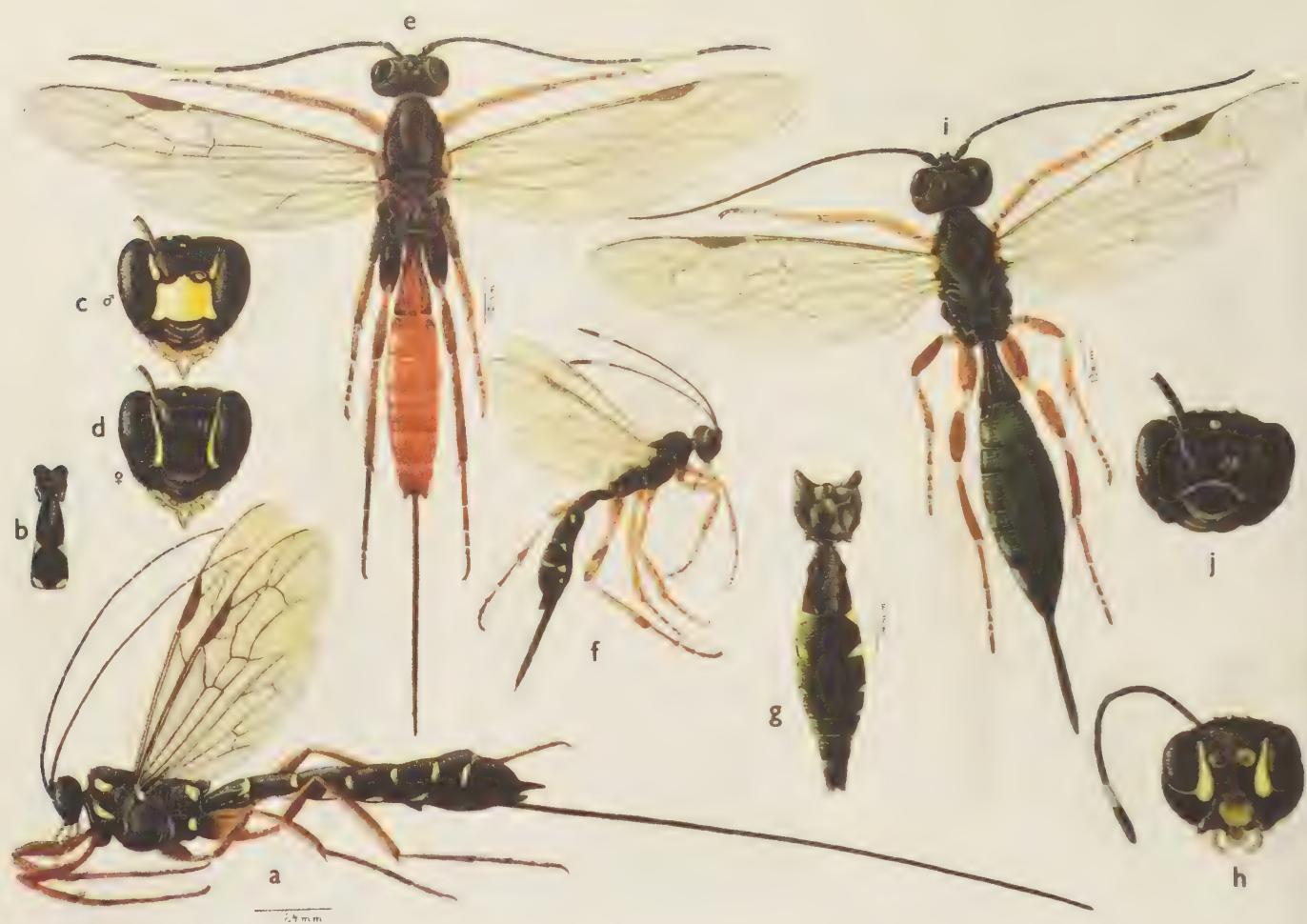
# Rhyssa persuasoria (L.)    Xorides filiformis (GRAV.)
# Xorides praecatorius (F.)    Ischnoceros rusticus (GEOFFR.)

a — *Rhyssa persuasoria* (L.) female; b — abdomen viewed from above; c—d — head; e — *Xorides filiformis* (GRAV.) female; f — *Xorides praecatorius.* (F.) female; g — propodeum and abdomen; h — head; i — *Ischnoceros rusticus* (GEOFFR.) female; j — head

*Rhyssa persuasoria* (L.) has a mat body. The mesothorax is roughly transversely wrinkled; the propodeum is undivided and finely transversely wrinkled, like the second and seventh segments of the abdomen. There is a border on the head behind the eyes. The males have a yellow face and orbits while, in the females, only the orbits are yellow. On the second to the seventh tergits of the abdomen there are circular yellow spots. The ovipositor is longer than the body. The wings are slightly smoky coloured. This species is 8 to 40 mm long. The larva is a parasitoid of saw-flies.

*Xorides filiformis* (GRAV.) has a mat body with a grainy surface. The tempora and part of the mesothorax are transversely wrinkled. The head is cube-shaped and broadens behind the eyes. Behind the centre of the antennae there is a ring of white segments and there is a white spot at the base of the tibiae. The ovipositor is shorter than the abdomen. In the central part of the forewings there is

a smoky-coloured spot. This species is 12 to 22 mm long and it parasitizes wood boring beetles.

*Xorides praecatorius* (F.) has a mat body with a fine grainy appearance; the propodeum is divided and the first tergite of the abdomen with longitudinae carinae. There is a yellow spot on the face, the antennae have a ring of white segments and the tempora has a typical rusty-coloured spot. The base of the pterostigma on the forewings is white. The ovipositor is shorter than the abdomen and the species is 6 to 12 mm long. It parasitizes xylophagous beetles and metallic-coloured woodborers.

*Ischnoceros rusticus* (GEOFFR.) has a shimmering body with fine punctures. The head has a hollow tooth between the antennae. The basal segments of the abdomen are finely transversely wrinkled and the wings are smoky. The ovipositor is shorter than the abdomen and the species is 7 to 16 mm long. It parasitizes xylophagous beetles.

# Therion giganteum (GRAV.)    Callajoppa exaltatoria (P.)
## Amblyjoppa fuscipennis (WESM.)

a — *Therion giganteum* (GRAV.) female; b — abdomen from a side view; c — head; d — pupa of *Dendrolimus pini* L. (pine moth) after the ichneumon has flown away; e — *Callajoppa exaltatoria* (P.) female; f — head; g — *Amblyjoppa fuscipennis* (WESM.) female; h — abdomen from a side view

The head and thorax of *Therion giganteum* (GRAV.) have dense rough spots. The propodeum has net-like wrinkled and the abdomen is compressed. The head and thorax are black with yellow spots. The scutellum is conic. The ovipositor is the same length as the height of the last segments of the abdomen. This species is 20 to 30 mm long and it parasitizes pests from the order *Lepidoptera*. It emerges from pine moth pupae through a circular hole.

*Calajoppa exaltatoria* (P.) has the body which is densely covered in fine spots; the sides, thorax and propodeum are wrinkled. The head narrows at the eyes and the scutellum conic. The third ventral segment does not have a longitudinal carina. The head is mostly rust-coloured and the hind segments of the abdomen are black with a slight metallic sheen. The ovipositor is nearly hidden. The wings are smoky-yellow coloured with smoky edges. It is 24 to 34 mm long and parasitizes the caterpillars of *Sphinx pinastri* L.

The body of *Amblyjoppa fuscipennis* (WESM.) has densely punctures. The head narrows behind the eyes, the scutellum is flat and the propodeum divided. The carinae are high. The head is black with yellow spots; the antennae are bristled, black and, in the female, have a ring of yellow segments. The abdomen is rusty-red and its first segment is black. The ovipositor is hidden and the wings are dark smoky-coloured. The species is 16 to 25 mm long and it parasitizes the caterpillars of sphinx moths.

## *Dolichomitus mesocentrus* (GRAV.)

a — female; b — from side view; c — cocoon with emergence hole; d — end of ovipositor from side view; e — g — process of egg deposition into host body

The head and thorax of *Dolichomitus mesocentrus* (GRAV.) are bright and with sparsely punctures while the propodeum and abdomen are densely dotted. The head narrows behind the eyes, the occipital carina is interrupted in the centre and the thorax is divided. The propodeum has a longitudinal carina. The first segment of the abdomen is nearly the same length as the second. From the second segment onwards, the hind borders are bright. In the males, the coxae of the second pair of legs have teeth. The body is black, the legs are ferugineous and the hind tibiae and tarsi are brown. The ovipositor is longer than the body and the teeth on the end are an identification characteristic for this species. This adaptation makes it possible for the females to deposit the eggs into wood. The ovipositor cuts successively deeper into the wood and oviposition lasts a long time. The length of the adult is 10 to 48 mm . The cocoon web of the larva is foliate and light brown. This ichneumonid parasitizes the larvae of wood-boring beetles.

## Phytodietus polyzonias (FÖRST.)    Itoplectis maculator (F.)
## Apechthis rufatus (GMEL.)    Glypta resinanae HTG.    Cephaloglypta murinanae (BAUER.)

a — *Phytodietus polyzonias* (FÖRST) female; b — *Itoplectis maculator* (F.) female; c — butterfly pupa after emergence of *Itoplectis*; d — *Apechthis rufatus* (GMEL) female; e — her head; f — *Glypta resinanae* HTG. female; g — *Cephaloglypta murinanae* BAUER female

*Phytodietus polyzonias* (FÖRST.) has a mat head, thorax is coriaceous. The abdomen is smooth and bright, and the thorax and propodeum are undivided. The ovipositor is nearly as long as the abdomen. The areola in the forewings is closed. The species is 7 to 8 mm long and it parasitizes the caterpillars of leaf rollers.

*Itoplectis maculator* (F.) has a bright body which is densely dotted; the head is transversal, inner margin of eye strongly concave and the propodeum is undivided. The ovipositor is less than half the length of the abdomen. The species is 8 to 12 mm long, widely polyphagous and a facultative secondary parasitoid of pupae. It emerges from the pupae of oak leaf rollers through a circular hole.

*Apechthis rufatus* (GMEL.) has a bright body; the head and thorax with finely punctures and the abdomen roughly dotted. The head is transversal and inner margin of eye weakly concave. The propodeum is not di-

vided. The ovipositor is as long as the first two segments of the abdomen and sharply bent at the end. It parasitizes the pupae of leaf roller, tent caterpillar moths and cabbage butterflies.

*Glypta resinanae* HTG. has a body with densely punctures; the head is transversal and the propodeum is partially divided. The second to the fourth tergits of the abdomen have a pair of dispersed divergent grooves. The ovipositor is longer than the abdomen. This species is 10 to 11 mm long and it parasitizes leaf rollers.

*Cephaloglypta murinanae* (BAUER) has a body with densely punctures; the vertex of the head has a deep hole in the centre with a longitudinal rupture. The scutellum is vaulted and the propodeum partially divided. The second and third tergits of the abdomen have a pair of divergent grooves. The base of the tibiae is white. This species is 7 to 8 mm long and is a dominant parasitoid of the silver fir needle roller.

# Triclistus podagricus (GRAV.)  Enicospilus ramidulus (L.)  Phaeogenes invisor (THNB.)
# Heteropelma calcator (WESM.)  Trieces tricarinatus (HOLMGR.)  Trichomma enecator
# (ROSSI)

a — *Triclistus podagricus* (GRAV.) female; b — head; c — *Enicospilus ramidulus* (L.) female; d — front view of its head; e — *Phaeogenes invisor* (THNB.); f — *Heteropelma calcator* (WESM.) female; g — roller pupa parasitized by this species; h — *Trieces tricarinatus* (HOLMGR.) female; i — *Trichomma enecator* (ROSSI) female; j — view from above

*Triclistus podagricus* (GRAV.) has a smooth, bright body, and head with densely punctures. This species parasitizes leaf rollers.

The body of *Enicospilus ramidulus* (L.) is coriaceous and the sides of the thorax with punctures. The ocelli are in contact with the compound eyes. The sides of the scutellum are sharp and the propodeum is transversely wrinkled. The abdomen is depressed from the sides and the forewings have two sclerites under the pterostigma. This species is 17 to 20 mm long and parasitizes the caterpillars of moths.

The ichneumonid *Phaeogenes invisor* (THNB.) has a bright, punctured body and a divided propodeum. The ovipositor extends only a negligible amount beyond the abdomen. The hind coxae have sharp teeth. This species is 7 to 9 mm long and is a frequent parasitoid of the oak leaf roller.

The ichneumonid *Heteropelma calcator* (WESM.) has a bright head and thorax, which are roughly punctured, and a propodeum with net-like wrinkles. The abdominal segments are compressed. The ovipositor is short and the wings are a smoky-yellow colour. This species is 12 to 16 mm long and is a parasitoid of geometrids. It emerges through a hole gnawed in the head of the host pupa.

*Trieces tricarinatus* (HOLMGR.) has a body with densely punctures; the scutellum ends in a sharp point and the propodeum is divided. The first abdominal segment has two ruptures while the second and third tergits have three longitudinal ruptures. This species is 5 to 6 mm long and parasitizes *Yponomeutidae* species.

*Trichomma enecator* (ROSSI) has a head and thorax with rough and dense punctures; the sides of the thorax are longitudinally wrinkled. The propodeum has net-like wrinkles. The segments of the abdomen are compressed. This species is 11 to 14 mm long and it parasitizes leaf rollers.

*Pristomerus vulnerator* (P.)   *Delopia oxyacanthae* (BOIE.)   *Temelucha buoliana* (CURT.)
*Banchus falcatorius* (F.)   *Ophion minutus* KRIECHB.

a — *Pristomerus vulnerator* (P.) female; b — hind femur; c — *Delopia oxyacanthae* (BOIE.) female; d — head; e — *Temelucha buoliana* (CURT.) female; f — head; g — *Banchus falcatorius* (F.) female; h — head; i — *Ophion minutus* KRIECHB. female

*Pristomerus vulnerator* (P.) has a densely punctured head, a mat thorax and a divided propodeum. The second abdominal segment is longitudinally wrinkled. The ovipositor is wavy at the end and the hind femora have sharp teeth. This species is 7 to 8 mm long and parasitizes the caterpillars of rollers.

*Delopia oxyacanthae* (BOIE.) has a densely punctured head and thorax and a mat abdomen. The propodeum has a central longitudinal depression and is transversely wrinkled. The eyes are cut out on the inner side. The abdomen is compressed. This species is 11 to 14 mm long and parasitizes geometrid.

The body of *Temelucha buoliana* CURT. is bright and densely punctured while the abdomen is mat and sparsely punctured; the propodeum is divided. From the third segment onwards, the abdomen is compressed. The ovipositor is half the length of the abdomen. There are yellow spots on the head and thorax. This species is 7 to 8 mm long. It parasitizes the caterpillars of rollers.

*Banchus falcatorius* (F.) has a head and thorax with densely punctures. The abdomen is smooth, bright and, from the third segment onwards, depressed from the sides. The frons of the head is concave. The propodeum has a high transverse carina and the ovipositor only extends a negligible amount beyond the abdomen. This species is 13 to 18 mm long. It parasitizes noctuid moths and geometrids.

*Ophion minutus* KRIECHB. has a bright smooth body; the propodeum is grainy and the abdomen is compressed. The head does not narrow behind the eyes, the ocelli are large and the antennae long. The tarsal claws are pectinate and ovipositor extends a negligible amount beyond the abdomen. It is 11 to 15 mm long and parasitizes the wintermoth.

## Lissonota folii THOMS.    Endasys erythrogaster (GRAV.)
## Scambus detritus (HOLMGR.)

*Lissonota folii* THOMS. has a mat body which is densely punctured and covered in a silvery felt. The propodeum is not divided and has a transverse carina. The abdominal segments are also transverse. The ovipositor is longer than the body, which is black with yellow spots on the head and prothorax. The abdominal tergits have light hind borders and, in the males, part of the segments is brown. This species is 6 to 8 mm long and the larval web is foliar and brown. It parasitizes the caterpillars of rollers and *Gelechidae.*

The head and thorax of *Endasys erythrogaster* (GRAV.) are densely punctured; the abdomen is smooth and bright, the tempora is broad and the antennae are robust. The thorax is flat and the furrow in front of the scutellum is divided by a longitudinal rib. The ovipositor is shorter than the abdomen. The head and thorax are black and the base of the antennae yellow. This species is 6 to 7 mm long and it parasitizes saw-flies.

*Scambus detritus* (HOLMGR.) has a smooth bright head and thorax; the abdomen, is densely roughly punctured and the hind borders of the tergits are smooth. The propodeum is not divided and the ovipositor is shorter than half the length of the abdomen. This species is black with dark brown antennae and abdomen and rust-coloured legs. The areola in the forewings is closed. It is 8 to 10 mm long and parasitizes rollers and *Yponomeutidae* species.

## Mesoleius marginatus BRISCHKE    Erromenus simplex THOMS.
## Pleolophus basizonus (GRAV.)    Lophyroplectus luteator THNB.
## Exenterus amictorius (P.)    Lamachus eques HTG.

a — *Mesoleius marginatus* BRISCHKE female; b — cocoon of a saw-fly parasitized by this species; c — *Erromenus simplex* THOMS. female; d — *Pleolophus basizonus* (GRAV.) female; e — *Lophyroplectus luteator* THNB. female; f — *Exenterus amictorius* (P.) female; g — *Lamachus eques* HTG. female

*Mesoleius marginatus* BRISCHKE has a mat coriaceous body. The ovipositor only extends a negligible amount beyond the end of the abdomen. The last ventral segment of the female is lancet-like. This species is 7 to 8 mm long. It parasitizes the larvae of saw-flies and leaves the web of the saw-fly through a circular hole.

The body of *Erromenus simplex* THOMS. is bright and punctured. The abdomen is densely roughly punctured and the scutellum ends in a sharp point. This species is 4 to 6 mm long and parasitizes saw-flies.

*Pleolophus basizonus* (GRAV.) has a punctured head and thorax; the propodeum is divided and a piece is cut out of the rear part. The abdomen is smooth and bright and the thorax flat. This species is 7 to 8 mm long and parasitizes saw-flies.

*Lophyroplectus luteator* THNB. has a mat body, a trans-verse head and a short divided propodeum. From the third segment onwards, the abdomen is compressed. There is a yellow striped sclerite under the pterostigma of the forewing. This species is 7 to 10 mm long and parasitizes the larvae of saw-flies.

*Exenterus amictorius* P. has a smooth body, a trans-verse head and a roughly punctured abdomen. The basal tergits are longitudinally wrinkled. This species is 7 to 9 mm long and parasitizes saw-flies of the genus *Diprion.*

*Lamachus eques* HTG. has a mat body. The head coriaceous, transverse. The propodeum is not divided. The colour of the body is black and there is a yellow spot between the antennae. This species is 8 to 11 mm long and parasitizes the larvae of saw-flies.

## Mesochorus vittator (ZETT.)  Gelis melanocephalus (SCHRANK)  Theronia atalantae (PODA.)
## Lysibia nana (GRAV.)  Dichrogaster aestivalis (GRAV.)  Diplazon laetatorius (F.)

a — *Mesochorus vittator* (ZETT.) female; b — part of shield from above; c — *Gellis melanocephalus* (SCHRANK); d — *Theronia atalantae* (PODA.); e — head; f — *Lysibia nana* (GRAV.); g — *Dichrogaster aestivalis* (GRAV.); h — *Diplazon laetatorius* (F.); i — puparium of flower saw-fly parasitized by this species

*Mesochorus vittator* (ZETT.) has a head and thorax, which are bright and sparsely punctured, the abdomen is smooth and bright, and the face is shield-like. The last ventral segment of the female is lancet-like. This species is 5 to 7 mm long. It is an important secondary parasitoid of braconids.

The body of *Gelis melanocephalus* (SCHRANK) is mat and coriaceous; the mesothorax is short and the propodeum has a transverse carina. Both sexes are wingless. This species is 3 to 5 mm long and parasitizes the egg bag of spiders.

*Theronia atalantae* (PODA) has a smooth, bright body and the thoracic scutellum is vaulted. It is a rusty colour with yellow spots on the head and black spots on the ventral part of the thorax and on the base of the abdomen. This species is 6 to 16 mm long. It is a secon-

dary parasitoid of tachinid-flies, ichneumonids and braconids.

The head and thorax of the *Lysibia nana* (GRAV.) are mat. The abdomen is bright and its first tergit is longitudinally grooved. The exterior genitalia of the males are tong-shaped. The species is 3 to 4 mm long. It is a parasitoid of braconids of the genus *Apanteles*.

The body of *Dichrogaster aestivalis* (GRAV.) is bright with shallow dots. The forewing has an open areola. The species is 3 to 5 mm long. It is a secondary parasitoid of green lacewings.

*Diplazon laetatorius* (F.) has a head and thorax which are smooth and bright; the popodeum and abdomen are roughly wrinkled or punctured. The tergits of the abdomen have a deep transverse depression. This species is 5 to 7 mm long and parasitizes the puparia of flower-flies.

## Acampsis alternipes (NEES)   Colastes braconius HAL.   Microplitis naenia NIX.
## Zoophthorus plumbeus (THOMS.)

a — *Acampsis alternipes* (NEES); b — cocoon; c — *Colastes braconius* HAL.; d — oak leaf with *Lithocolletis* parasitized by this braconid; e — *Microplitis naenia* NIX.; f — cocoon; g — *Ichneumonid Zoophthorus plumbeus* (THOMS); h — cocoon of *Bucculatrix thoracella* THNB. with emergence-hole of this ichneumonid

*Acampsis alternipes* (NEES) is a robust species of braconid and 6 to 8 mm long. It is a specific endoparasitoid of geometrids of the genus *Alsophila*, which are destructive pests of oaks and other broad-leaved trees. The cocoon of this species is silvery-white, bright, smooth and 5 to 6 mm long with an irregular emergence hole.

The braconid *Colastes braconius* HAL. is a small, slim species and 2 to 4 mm long. It is dark brown. This species is specialized on mining hosts of some insect orders (*Lepidoptera, Coleoptera, Hymenoptera* and *Diptera*). It is a solitary ectoparasitoid. Parasitization of species of the genus *Lithocolletis* on oak leaves is indicated by holes in the host mines.

*Microplitis naenia* NIX. is a minute braconid species, 2.5 to 3.5 mm long, with yellow-brown legs and black coxae and trochanter. The antennae have 18 segments.

The body surface is very fine, smooth and bright. The ovipositor is very short. It is a solitary endoparasitoid of caterpillars of the younger instars of noctuid moths of the genera *Orthosia* and *Eupsilia*. Its cocoon is pale brown with striking white ribbing, 3.5 mm long, and the emergence hole is regular.

The ichneumonid *Zoophthorus plumbeus* (THOMS.) has a mat and coriaceous body; the sides of the thorax and the hind tergites of the abdomen are smooth and bright. The clypeus does not have teeth or tubercles on the front border. The propodeum is divided. The body and coxae are black, the rest of the leg is light brown, and the femora and tops of the tibiae are dark brown. This species is 2 to 3 mm long and an important endoparasitoid of *Bucculatrix thoracella* THNB. At hatching, the imago gnaws a circular hole beneath the top of the host web.

# Dendrosoter middendorffii RATZ.    Coeloides bostrichorum GIR.
# Ropalophorus clavicornis (WESM.)

The braconid *Dendrosoter middendorffii* RATZ. is of variable size, 2.5 to 5 mm long, it is brown-black and the larger part of the head, the base of the antennae, the sides of the thorax, the central part of the second tergite and the legs are red-brown. The wings are more or less dark with traces of lighter bands; the pterostigma is light brown with a pale yellow base. The males also have a prerostigma on the hindwing. The frons is vaulted on the sides in a hen's comb shape. The antennae have 24 to 26 segments and are the same length as the body. The head and thorax have a fine granular surface. The first tergite and the half-moon-like part of the second tergite have fine longitudinal grooves. It is a solitary ectoparasitoid of bark beetle larvae mainly on conifers, for instance, of the spruce bark beetle *Ips typographus* L.

*Coeloides bostrichorum* GIR. is a minute species, only 2.5 to 4 mm long, the head and abdomen are yellow brown and the thorax is black. Both the antennae, which have 31 to 37 segments, and the ovipositor are longer than the body. The surface of the body is fine and smooth. This species is a solitary ectoparasitoid of bark beetle larvae. It is often the most important parasitoid of the spruce bark beetle *Ips typographus* L.

*Ropalophorus clavicornis* (WESM.) is a small species. 2.5 to 3 mm long. The body is a resin-like brown colour and the legs and antennae are a lighter brown. The antennae are strikingly bent and their scape forms about one fourth of the total length. It is a solitary endoparasitoid of the adults of the spruce bark beetle *Ips typographus* L. It often occurs in hibernating adults of the bark beetle. The female of this braconid pierces the suture between the elytra with her ovipositor to deposit eggs in the bark beetle.

*Aspicolpus carinator* (NEES.)    *Helcon tardator* NEES.    *Bracon hylobii* RATZ.

a — *Aspicolpus carinator* (NEES.); b — *Helcon tardator* NEES.; c — cocoon; d — larval galleries of longhorned beetle *Plagionotus arcuatus* L. with cocoons of this braconid; e — *Bracon hylobii* RATZ. male; f — its eggs on the body of larva of the large brown pine weevil; g — its cocoons; h — larvae on the larva of large brown pine weevil.

*Aspicolpus carinator* (NEES.) is a robust species of braconid, 8 to 11 mm long, with a cubic head and black coloration except for the base of the antennae, the wing covers and the legs which are red-brown. Only the first two tergites of the abdomen are wrinkled; the others are smooth. It is a solitary endoparasitoid of the larvae of longhorned beetles.

*Helcon tardator* NEES. is 10 to 14 mm long, with a cubic head; it is black, with red-brown wing covers and legs and darker hind tibiae and tarsi. The antennae have 20 to 36 segments and the ovipositor is only a little shorter than the body. The body surface is fine; only the propodeum and the first two abdominal tergites are wrinkled. It is a solitary endoparasitoid of the larvae of longhorned beetles. The cocoon of this species is red-brown with an irregular emergence hole. This species occurs in the larval galleries of the host since it is visible in the larval gallery of *Plagionotus arcuatus* L.

*Bracon hylobii* RATZ. is 3 to 3.5 mm long. The head and thorax of the male are brown-black and the abdomen is yellow-brown; the first and second tergites mostly have black spots; also the end of the abdomen is black. The antennae are somewhat longer than the body and have 32 to 38 segments. The body surface is smooth and shiny; only the propodeum is finely wrinkled. It is a major and often important ectoparasitoid of the large brown pine weevil *Hylobius abietis* L. and other weevils. The female deposits her eggs on the larval body of the pine weevil as can be seen in Table 37. Before the deposition of the eggs, this braconid paralyses the host larva by piercing it with her ovipositor. So the larvae of *B. hylobii* RATZ. live ectoparasitically on the immobilized larva of the large brown pine weevil. They pupate in the larval gallery of the host; the cocoons are whitish, transparent and mutually connected.

## Dendrosoter protuberans NEES  Doryctes leucogaster NEES  Atanycolus initiator F.
## Ontsira antica WOLL.  Ecphylus silesiacus (RATZ.)

a — *Dendrosoter protuberans* NEES female; b — *Doryctes leucogaster* NEES female; c — *Atanycolus initiator* F. female; d — *Ontsira antica* WOLL. female; e — *Ecphylus silesiacus* (RATZ.) female

The braconid *Dendrosoter protuberans* NEES is minute, 2.5 to 4 mm long, and brown-black with a lighter brown head and some spots on the thorax and legs. On both sides of the head, there are extended tubercles in the form of combs. The antennae have 29 segments and are somewhat longer than the body while the ovipositor is somewhat shorter. It is a solitary ectoparasitoid of the larvae of bark beetles, mainly broad-leaved tree species.

*Doryctes leucogaster* NEES is a braconid of variable size from 3 to 10 mm long with a cubic head. The antennae have 57 to 60 segments and are of the same length as the body; the ovipositor is somewhat shorter. It is a solitary ectoparasitoid of the larvae of longhorned beetles, for instance, *Rhagium inquisitor* L.

*Atanycolus initiator* F. is a larger species 7 to 11 mm long, and its head is cube shaped. The antennae have 49 to 54 segments and are only little shorter than the body. It is a solitary ectoparasitoid of longhorned beetles, e.g., *Rhagium inquisitor* L.

*Ontsira antica* WOLL. is a 3 to 5 mm long braconid. Its head and thorax are mainly black, and the abdomen, from the second tergite onwards, and the legs are brown. The antennae have 33 segments and are as long as the body; the ovipositor is a little longer than half the length of the abdomen. It is a solitary ectoparasitoid of the larvae of longhorned beetles, for instance, *Plagionotus arcuatus* L.

*Ecphylus silesiacus* (RATZ.) is a minute braconid, 1 to 3 mm long; it is variable in size, coloration and surface texture. The antennae have 13 to 16 segments and are about the same length as the body; the ovipositor is somewhat longer than the abdomen. The coloration varies from black to yellow-brown. The thorax is wrinkled; the first abdominal tergite is longitudinally grooved while the others are smooth. It is a solitary ectoparasitoid of the larvae of a wide variety of species of bark beetles. The variation in its characteristics is conditioned by the size of the host.

## Coeloides filiformis (RATZ.)   Eubazus atricornis (RATZ.)
## Bracon hylobii RATZ.   Spathius rubidus (ROSSI)

a — *Coeloides filiformis* (RATZ.) female; b — male; c — *Eubazus atricornis* (RATZ.) female; d — cocoon; e — abdomen from side view; f —*Bracon hylobii* RATZ. female (male is pictured in Tab. 35); g — *Spathius rubidus* (ROSSI) female

*Coeloides filiformis* RATZ. is a braconid of average size, 4 to 5 mm long, and is a solitary ectoparasitoid of bark beetles, for instance, *Hylesinus fraxini* PANZ. on ash. It exhibits pronounced sexual dimorphism. The male is longer than the female, his abdomen is longer and flattened from above. The body is brown-black and the antennae have 33 segments.

*Eubazus atricornis* (RATZ.) is a more robust braconid, 3 to 5 mm long, and only the legs are mostly yellow-brown. The first three abdominal tergites are obvious; the first two of these are longitudinally grooved; the third is smooth and further tergites protrude narrowly behind it. It is a solitary endoparasitoid of the larvae of pine weevils of the genus *Pissodes*. The eggs are deposited into the eggs of the host. This species is an egg-larval parasitoid and is the most important control fac-

tor of the larvae of *Pissodes piceae* ILL. More than 40 % of the larvae are attacked by this braconid. The cocoon is parchment-like, light yellow-brown and transparent.

*Bracon hylobii* RATZ. The bionomics and main characteristics of this species are given in the description of the male (Tab. 35).

*Spathius rubidus* (ROSSI) is a minute species, 2 to 4 mm long, with a striking stalk-like abdomen. The body is brown and the end of the abdomen a darker brown-black. The antennae which have 28 to 30 segments, are longer than the body; the ovipositor is less than half the abdomen's length. The first tergite and the front part of the second are finely grooved; the other tergites and the head are smooth. It is a solitary ectoparasitoid of the larvae of beetles living beneath bark, for instance, *Hylesinus fraxini*.

*Oncophanes laevigatus* (RATZ.)    *Aleiodes testaceus* F.    *Charmon extensor* (L.)
*Ascogaster rufidens* WESM.    *Microgaster hospes* MARSH.

a — *Oncophanes laevigatus* (RATZ.) female; b — cocoons; c — *Aleiodes testaceus* F. male; d — mummy of caterpillar parasitized by this species; e — *Charmon extensor* (L.) female; f — cocoon; g — *Ascogaster rufidens* WESM. female; h — *Microgaster hospes* MARSH. female

*Oncophanes laevigatus* (RATZ.) is a minute braconid. 2 to 3 mm long. The first tergite and the smaller part of the second have fine longitudinal grooves; the other tergites are smooth and bright. It is a gregarious ecto-parasitoid of caterpillars forming webs, for instance, the green oak leaf roller *Tortrix viridana* L. Usually three to five larvae of this braconid develop on one caterpillar.

*Aleiodes testaceus* F. is a braconid of average size, 5 to 5.5 mm long, and all one colour (yellow-brown). The first two tergites of the abdomen have a mean carina. The ovipositor does not extend beyond the abdomen. It is a gregarious endoparasitoid of *Notodontidae* caterpillars, for instance, *Cerura vinula* L. The larvae of the last instar impregnate the integument using their exudate.

*Charmon extensor* (L.) is a more robust, slender braconid, 4.5 to 6 mm long, and dark brown; the thorax and legs are light yellow-brown. It is a solitary endoparasitoid of many species of microlepidoptera, for instance,

the green oak leaf roller (*Tortrix viridana* L.). The cocoon is oblong, parchment-like with a fibre covering the surface, and orange-brown. The emergence hole is irregular and, the spun remains of the host caterpillar are on the pole opposite it. .

*Ascogaster rufidens* WESM. is a braconid of mean size, 4 to 5 mm long; a typical characteristic is that the abdominal tergites grow, and fuse together in the shell. It is a solitary endoparasitoid of various tortricids, for instance, *Eudemis profundana* D. SCH. The female deposits eggs into host eggs, the larva develops in host caterpillars. The emergence hole is irregular and the spun remains of the host caterpillars are on the pole opposite it.

*Microgaster hospes* MARSH. is a braconid of mean size, 3 mm long, black, only legs are mostly red-brown. It is a solitary endoparasitoid of caterpillars of tortricids, for instance, *Eudemis profundana* D. SCH. The cocoon is silver white, with fibrious surface. The emergence hole is regular, and on the pole opposite it, are the spun remains of the host caterpillar.

## Agathis lugubrator (RATZ.)   Cosmophorus klugii RATZ.
## Macrocentrus linearis (NEES)   Baeognatha nigra TEL.

a — *Agathis lugubrator* (RATZ.); b — *Cosmophorus klugii* RATZ.; c — *Macrocentrus linearis* (NEES); d — joint cocoon; e — *Baeognatha nigra* TEL.; f — case of casebearer

*Agathis lugubrator* (RATZ.) is a small, slender braconid, 2.5 to 3 mm long. The body is black and the legs are red-brown. The antennae which have 26 to 28 segments, are as long as the body; the ovipositor is the same length as the abdomen. The head and thorax are smooth and the propodeum finely wrinkled; the first abdominal tergite is longitudinally grooved, the second is dotted and the others are smooth. It is a solitary endoparasitoid of the caterpillars of casebearers of the genus *Coleophora*, for instance, *C. lutipennella* ZELL. This braconid pupates in the case of the host caterpillar and creeps out from between its valvules.

*Cosmophorus klugii* RATZ. is a minute, resin-brown to black-coloured braconid, 2 to 2-5 mm long, with a striking cubic head bearing large mandibles (the male has smaller mandibles). The females use these mandibles to seize bark beetles for deposition of the eggs. This species is a solitary endoparasitoid of bark beetle adult. It pupates in a yellowish paper-like cocoon not far from the dead adult host.

*Macrocentrus linearis* (NEES) is a slender braconid, 3.5 to 5 mm long, prevailingly yellow-brown although the abdomen (mainly the hind part) is darker brown. It is a gregarious endoparasitoid of the caterpillars of various butterflies with frequent polyembryony, for instance, the roller *Choristoneura hebenstreitella* MÜLL. It forms a joint cocoon (from loose tissue) which includes individual cocoons.

*Baeognatha nigra* TEL. is a minute braconid, 3 mm long, and black with legs that are partially red-brown. The antennae are about as long as the body and the ovipositor is approximately the same length as the abdomen. The head and thorax are finely dotted, and the propodeum, like the first two tergites of the abdomen, is wrinkled; the other tergites are smooth. It is a solitary endoparasitoid of the caterpillars of the casebearer *Coleophora lutipennella* ZELL., like the braconid species *Agathis lugubrator* (RATZ.)

# Earinus nitidulus (NEES)    Zele albiditarsus CURT.    Meteorus versicolor (WESM.)

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a — *Earinus nitidulus* (NEES); b — cocoon; c — *Zele albiditarsus* CURT.; d — cocoon; e — *Meteorus versicolor* (WESM.); f—g — cocoon

*Earinus nitidulus* (NS.) is a robust species, 6 to 7 mm. long, and black; the wing covers and legs are red--brown. The antennae have 37 segments and are a little shorter than the body; the ovipositor is the same length as the abdomen. The head and thorax are finely dotted. the propodeum has two longitudinal carinae and the abdomen is smooth. It is a solitary endoparasitoid of the caterpillars of noctuid moths, for instance, *Orthosia stabilis* D.SCH. The cocoon is silvery white and the opaque surface is rarely fibrous. The remains of the host caterpillar are spun onto the cocoon. The emergence hole is regular.

*Zele albiditasus* CURT. is a robust braconid and 8 to 11 mm long. The body is rusty yellow while the stemmaticum, the tips of the mandibles and the ends of the antennae are darker and, to the contrary, the hind tarsi are whitish. It is a solitary endoparasitoid of the caterpillars of noctuid moths, for instance, the pine beauty, *Panolis flammea* D. SCH. The cocoon is found in litter, has a few layers and is spindle-shaped; its surface layer is felt-like, fibrous and pale yellow-brown.

*Meteorus versicolor* (WESM.) is a braconid of average size, 3.5 to 5 mm long, red-yellow in colour with a stalk-like abdomen. The antennae, which have 27 to 35 segments, are longer than the body; the ovipositor is somewhat longer than half the abdomen's length. The head and thorax are finely dotted and the propodeum wrinkled; the hind half of the first tergite is finely grooved while the other tergites are smooth. It is a solitary endoparasitoid of the caterpillars of tussock moths, for instance, *Euproctis chrysorrhoea* L. The cocoon is spindle-shaped, brown, parchment-like and nearly transparent (the larval exuviae shine through), and the surface is rarely fibrous. It often hangs on a 3 to 7 cm long fibre with the head of the braconid pointing downwards.

## Apanteles porthetriae MUES.   Apanteles gastropachae (BCHÉ)
## Apanteles murinanae ČAP. et ZW.   Apanteles melanoscelus (RATZ.)
## Apanteles liparidis (BCHÉ)

a — *Apanteles porthetriae* MUES., b — *Apanteles gastropachae* (BCHÉ.); c — *Apanteles murinanae* ČAP. et ZW.; d — *Apanteles melanoscelus* (RATZ.); e — cocoon; f — *Apanteles liparidis* (BCHÉ.)

*Apanteles porthetriae* MUES. is a braconid of average size, 3 mm long, with black wing covers; most of the legs and the margins of the first and second abdominal tergites are yellow. This species is a solitary endoparasitoid of young caterpillars of the gypsy moth, *Lymantria dispar* L. At some localities, it is an important entomophagous enemy of this pest.

*Apanteles gastropachae* (BCHÉ) is also a braconid of average size, 2 to 3 mm long; the body is black and the legs and the narrow margins of the first three tergites of the abdomen are red-yellow. It is a gregarious endoparasitoid of *Malacosoma neustrium* L.

*Apanteles murinanae* ČAP et ZW. is a minute braconid of average size, 3.5 to 4 mm long, with a black body and legs which are only partially brown. This species is a solitary endoparasitoid of the caterpillars of *Choristoneura murinana* HBN. It has a whitish, paper-like, opaque cocoon which is usually spun onto a needle and mostly also onto the remains of the host. The emergence hole is regular.

*Apanteles melanoscelus* (RATZ.) is a minute braconid, 2 to 2.5 mm long; it is black with whitish palpae and legs which are yellow-brown from the larger part onwards. This species is a solitary endoparasitoid of the younger caterpillars of tussock moths, for instance, the gypsy moth *Lymantria dispar* L.; it is an important entomophagous enemy of this pest. The cocoon is dirty white to yellow, solid and rarely fibrous; it is mostly attached to tree stems and is usually hidden from above by the remains of the host caterpillar.

*Apanteles liparidis* (BCHÉ) is a minute species, 2 to 2.5 mm long; the body is black and the palpae, legs and narrow margins of the first three tergites of the abdomen are yellow-brown. It is a gregarious endoparasitoid of caterpillars of the gypsy moth, *Lymantria dispar* L. The whitish cocoons occur in irregular clusters on tree stems with the spun remains of the host caterpillar. The emergence hole is regular.

## Apanteles octonarius (RATZ.)  Apanteles lacteicolor VIER.
## Apanteles praepotens (HAL.)  Apanteles spurius (WESM.)

a — *Apanteles octonarius* (RATZ.); b — cocoons; c — *Apanteles lacteicolor* VIER.; d — cocoons; e — *Apanteles praepotens* HAL.; f — cocoon; g — *Apanteles spurius* (WESM.); h — cocoons

*Apanteles octonarius* (RATZ.) is a minute species, 2 to 2.5 mm long; it has a black body and the palpae, the legs from the larger part onwards and the margins of the first two tergites are yellow. The antennae have 18 segments and are longer than the body while the ovipositor is very short. The head and thorax are smooth; the propodeum and the first abdominal tergite are very finely wrinkled and the other tergites are smooth. It is a gregarious endoparasitoid of arctiids, for instance, *Eilema deplana* ESP. The cocoons are dirty white and are spun together with the remains of the host caterpillar onto twigs in irregular clusters.

*Apanteles lacteicolor* VIER. is also a minute species, 2.5 mm long, and black with legs which are partially brown. This species is a solitary endoparasitoid of the young caterpillars of tussock moths, for instance, *Euproctis chrysorrhoea* L. The cocoons are pure white and rarely fibrous.

*Apanteles praepotens* (HAL.) is a species of average size, 3 to 3.5 mm long; the body is black and the palpae

and part of the legs are light brown. It is a solitary endoparasitoid of the caterpillars of geometrids, for instance, the winter moth, *Operophtera brumata* L. The cocoon is yellow-white and rarely fibrous, the emergence hole is regular, and the remains of the host caterpillar are often spun onto it.

*Apanteles spurius* (WESM.) is a species of average size, 2.8 to 3.2 mm long, with a black body and legs which are only partially brown. The antennae have 18 segments and are the same length as the body; the ovipositor is very short and hardly protrudes from the body. The head and thorax are dotted; the propodeum and the first and second tergites of the abdomen are wrinkled; the other tergites are smooth. It is a gregarious endoparasitoid of the caterpillars of geometrids, noctuid moths and lasiocampids. The cocoons occur in irregular clusters around the remains of the host; they are dirty white, yellowish and sometimes rosy. The emergence holes are regular.

## Pygostolus multiarticulatus (RATZ.)   Meteorus lionotus THOMS.
## Orgilus obscurator NEES   Macrocentrus buolianae EADY et CL.

*Pygostolus multiarticulatus* (RATZ.) is a more robust braconid, 6 to 8 mm long and rusty yellow-coloured. This species is a solitary endoparasitoid of adult beetles. The cocoon is spindle-shaped, parchment-like translucent and grey; it has a regular emergence hole and is often attached to needles.

*Meteorus lionotus* THOMS. is a braconid of average size, 5 mm long; the body is rusty yellow. It is a solitary endoparasitoid of the caterpillars of moths on conifers, for instance, *Thera juniperata* L. The cocoon is honey-brown, parchment-like translucent, and rarely fibrous on the surface. It hangs, as a rule, on a fibre up to 10 cm long with the braconid's head pointing downwards. The emergence hole is regular.

*Orgilus obscurator* NEES is also average-sized, 3 to 4 mm long, with a black body and legs which are partially lighter. The antennae have 35 segments and are as long as the body; the ovipositor is the same length. The head and thorax are finely dotted and the propodeum wrinkled; the first and second tergites of the abdomen have fine longitudinal grooves while the others are smooth. This species is a solitary endoparasitoid of the caterpillars of microlepidoptera. It is the most important parasitoid of the European pine shoot moth, *Rhyacionia buoliana* D. SCH. The cocoon is fine, translucent and has fine fibres; it is mostly yellow-coloured and, as a rule, is hidden in the feeding areas of the host in pine buds. The emergence hole is irregular.

*Macrocentrus buolianae* EADY et CL. is a slender braconid, 5 mm long, with a yellow-brown body; the propodeum and the base of the abdomen are darker. The antennae have 43 to 45 segments and are longer than the body; the ovipositor is a little shorter. The head and thorax are smooth and the propodeum has transverse grooves; the first two tergites of the abdomen have fine longitudinal grooves and the others are smooth. It is a major endoparasitoid of the European pine shoot moth, *Rhyacionia buoliana* D. SCH. The cocoons are usually found in a group; they are dark red-brown, a regular emergence hole.

## Tomicobia seitneri RUSCH.    Pachyceras xylophagorum RATZ.
## Rhopalicus tutella WALK.

a — *Tomicobia seitneri* RUSCH. male; b — female; c — bark beetle with emergence hole of *Tomicobia seitneri* RUSCH.; d — *Pachyceras xylophagorum* RATZ.; e — larvae of bark beetle parasitized by this species; f — *Rhopalicus tutella* WALK. female; g — male

*Tomicobia seitneri* RUSCH. males are 2.5 to 5.5 mm long, metallic green and their wing venation, as in all chalcid-flies, is very reduced. The female has an ovipositor on the lower side of the abdomen which is not visible from above. She inserts the ovipositor into the suture between the elytra of bark beetles and deposits the eggs. The adult pteromalid emerges from the bark beetle through a circular hole. *T. seitneri* RUSH. has two to three generations per year and is a really important parasitoid of bark beetles.

*Pachyceras xylophagorum* RATZ. is similar to *T. seitneri* but is mostly a darker green with a copper hue. The female has a brown abdomen. The life cycle is the same as that of the preceding species.

*Rhopalicus tutella* WALK. is 2.5 to 4 mm long with a distinct sexual dimorphism. The head and thorax of the male is dark green-brown, the abdomen is brown and there is a circular spot on the wings. The female is green-brown, without the brown spots on the wings and abdomen, and has a sharp ovipositor. It is an important parasitoid of bark beetles. The eggs are inserted through the bark directly into the larvae or pupae of bark beetles, and the hatched imagines gnaw out through circular holes. It is a typical parasitoid of bark beetles living beneath thin bark. At mass outbreaks of bark beetles it is very abundant and even 100 % parasitism has been recorded. It is also important that it parasitizes bark beetles in the bark of stems stored in dark forest stands.

# Trichogramma evanescens WESTW.    Perniophora robusta RUSCHKA
## Telenomus laeviusculus RATZ.

*Trichogramma evanescens* WESTW. is only a 0.5 mm long insect, brown-coloured, with strikingly large eyes; the wings have a very reduced venation of only one short vein. The antennae of the male are longer than those of the female. It is a highly polyphagous parasite of the eggs of numerous butterflies. The eggs it most parasitizes are those of the pine moth *Dendrolimus pini* L., *Malacosoma neustrium* L., *Panolis flammea* D.SCH and also of some species of saw-flies, mainly of the genus *Cephaleia*. After hatching of these minute eggs parasites, oval holes remain in the eggs; there is usually more than one in each egg. This species does not occur frequently but it is important because its parasitization of eggs prevents the hatching of caterpillars. Very often all of the eggs deposited are parasitized.

*Perniophora robusta* RUSCHKA is a 2 to 3 mm chalcidoid-fly which is a parasitoid of the larvae of the lineate bark beetle. The female is completely green and the ovipositor is hidden beneath the body. The male is brown. The species penetrates into the tunnels of the bark beetle and inserts the eggs directly into its larvae. The larvae of *P. robusta* RUSCHKA live ectoparasitically.

The scelionid *Telenomus laeviusculus* RATZ. is a member of the *Proctotrupoidea* superfamily and is only 1.5 to 2 mm long. This insect is brown-black with typically bent antennae and hairy eyes. It is an important parasitoid of larger butterflies. From 1940 to 1949, it was an important parasitoid of the eggs of the pine moth, *Dendrolismus pini* L. during an outbreak in the central Labe lowland in Bohemia; the parasitization rate was up to 60 %.

*Eulophus larvarum* ʟ.    *Brachymeria intermedia* (NEES.)    *Pteromalus puparum* ʟ.

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a — *Eulophus larvarum* L.; b — *Brachymeria intermedia* (NEES.); c — *Pteromalus puparum* L.

With pests that have regular outbreaks at an interval of every few years with the result of clear feeding of a forest area, certain parasitoids play an important role. An example of this is the importance of three species of chalcidoid-flies, which, during the years of the mass reproduction of *Tortrix viridana* ʟ, reduce the population of this pest to a minimum in one season so that its occurrence is minimal, negligible or even scarce the following year. These three species of parasitoids are as follows:

*Eulophus larvarum* ʟ is 2 mm long. It is a lovely green chalcidoid-fly with a pronounced surface texture of the thorax and bright abdomen. The nerves of the wings are reduced to one vein.

One of the largest species of chalcid-flies is *Brachymeria intermedia* NEES. It is 6 mm long, black with a robust thorax covered in spots. The abdomen is bright and black. The legs are partially a contrasting sulphur-yellow; the femora of the hind pair are strengthened and allow the species to leap. Although this species prefers to parasitize mainly the pupae of the leaf skeletonizer moths, *Zygenidae,* it is the main parasitoid of the green oak leaf roller *Tortrix viridana* ʟ, during its outbreaks. Up to 75% of the pupae of the green oak leaf roller are parasitized by this parasitoid.

*Pteromalus puparum* ʟ is the same size as *E. larvarum* ʟ. The abdomen is bright metallic blue. It takes part in the parasitization of the green oak leaf roller together with the preceding species although the number of its hosts is large. During the years of an outbreak of the cabbage butterfly, most of its overwintering pupae are also parasitized by this species, which is abundant everywhere.

## *Trioxys pallidus* (HAL.)   *Aphidius setiger* MACK.   *Praon flavinode* (HAL.)

a — *Trioxys pallidus* (HAL.); b — aphid parasitized by this species; c — aphid after hatching of parasite; d — *Aphidius setiger* MACK.; e — aphid parasitized by this species after hatching of parasite; f — *Praon flavinode* (HAL.); g — aphid parasitized by this species with typical cocoon of parasite

*Trioxys pallidus* (HAL.) is a 1.7 mm long, yellow-brown species with a considerably reduced wing venation. The female possesses forked outgrowths on the end of the abdomen and uses them to hold the attacked aphid during oviposition. It pupates within the parasitized aphid. The mummies of the aphids are yellow to yellow-white. It is a parasitoid specialized on certain aphids of the family *Callaphididae* on oak, elm, hornbeam, hazel-nut and walnut trees.

*Aphidius setiger* MACK. is a species of average size, 2.1 mm long; it is yellow-brown with an averagely reduced wing venation system. Pupation takes place within the parasitized aphid. The mummies of the aphids are yellowish to yellow-white. It is a specialized parasitoid of aphids of the genus *Periphyllus* on maple trees.

*Praon flavinode* (HAL.) is a 1.7 mm long, minute, yellow-brown species with an averagely reduced wing venation system. Pupation takes place under the parasitized aphid; the aphid mummy is attached to the upper part of the parasite's cocoon, which is whitish. It is a parasite specialized on a series of aphids of the family *Callaphididae* on birch, oak, elm, hornbeam and lime trees.

*Ephedrus prociphili* STARÝ   *Aphidius schimitscheki* STARÝ   *Pauesia laricis* (HAL.)

a — *Ephedrus prociphili* STARÝ; b — mummy of aphid parasitized by this species; c — *Aphidius schimitscheki* STARÝ; d — aphid parasitized by this species; e—f — aphid with exit holes of hyperparasitoids and with small holes of predators; g — *Pauesia laricis* (HAL); h —parasitized aphid after hatching of this parasitoid

*Ephedrus prociphili* STARÝ is only 3.7 to 4.0 mm long; it is a brown-black species with full wing venation. Pupation takes place inside the dead parasitized aphid. The aphid mummies are of a characteristic black colour. It is a specialized parasitoid of aphids of the genus *Prociphilus,* which form large gall clusters on ash leaves. After hatching of the parasitoid the mummified aphids possess a characteristic circular hole. The lid of the hole is often broken off.

*Aphidius schimitscheki* STARÝ is a minute species, only 1 mm long; it is brown-coloured with an averagely reduced wing venation system. Pupation takes place inside the parasitized aphid. The aphid mummy is yellow to yellow-white. It is a specialized parasitoid of the aphid *Elatobium abietinum* (WALK.) which has massive outbreaks on sitka spruce. The mummified aphids have a round hole after hatching of the parasitoid. If some

holes with irregular margins occur in the same population of parasitized aphids (as in Figs. e—f), then hyperparasitoids are involved. Besides this, small holes can be caused by predators. In such cases, it is difficult to identify the species which occurred on the aphid as either parasitoids or predators.

*Pauesia laricis* (HAL.) is a 4 mm long, brown and yellow-orange coloured species with an averagely reduced wing venation system. Pupation takes place within the parasitized aphid. The mumies of the aphids are yellow or brown to brown-black depending on species. It is a parasitoid specialized on aphids of the genus *Cinara* on conifers. The parasitized aphids often migrate from the colonies before their death. The mummies of parasitized *Cinara pinea* MORDVILKO have a characteristic round hole after hatching of the parasitoid. The lid of the hole often drops off.

## Parasetigena agilis R.D.    Exorista larvarum L.

a — *Parasetigena agilis* R.D.; b—c — head from side and front views; d — larva; e — puparium; f — caterpillar of nun moth with eggs of tachinid-fly; g — *Exorista larvarum* L.; h — head from side and front wiews; j — puparium

*Parasetigena agilis* R.D. females are 8 to 12 mm long and similar in coloration to the well-known common blow-fly. The eyes have fine hairs which are red-brown; the frons is whitish yellow, the frontal band is brown-black, and the bristles on the sides of the face reach the black antennae. The body is brown-black and on the thorax there are four dark, but not too pronounced, longitudinal stripes; the scutellum is dark at the root and yellow at the back. There are larger yellowish spots on the abdomen. The femora have long hairs and the wings are brownish at the roots. These characteristics facilitate identification of this species which flies from the end of May to the end of July. It parasitizes the caterpillars of tussock moths, mainly of the nun moth and the gypsy moth. During the years of nun moth outbreaks, it is of great importance although it has only one generation per year. It can destroy up to 80 % of the caterpillars. Otherwise it seldom occurs. The female deposits her white eggs on all of the

instars of the caterpillars, mainly individually although a larger number of eggs are laid but only on more fully grown caterpillars.

*Exorista larvarum* L. is similar to *P. agilis* R.D. However, it differs in that it has bare eyes, the frontal black band is narrower, there are darker continuous longitudinal stripes on the thorax, and the abdomen is more cone-shaped, is brown-black and the spots on it are more pronounced. The length of the body is 6 to 10 mm so that *E. larvarum* L. is a much smaller species than the preceding one. This species does not occur frequently and parasitizes the caterpillars of many moth species, most often those of leaf skeletonizer moths. At a massive outbreak of the nun moth, *Lymantria monacha* L., and the gypsy moth, *Lymantria dispar* L., and at larger outbreaks of *Euproctis chrysorrhoea* L., this species is, as a rule, of considerable importance because it has two generations per year.

*Ernestia rudis* FALL.    *Agria affinis* FALL.

a — *Ernestia rudis* FALL.; b—c — head; d — puparium; e — larvae after hatching; f—g — *Agria affinis* FALL.; h — puparium; i — larva in funnel in the vicinity of air tubes (tracheae)

*Ernestia rudis* FALL. is a robust, 10 to 15 mm long fly; the body is dusty grey and slightly bright. This species occurs frequently in pine forests. From spring onwards, these tachinid-flies sit on sun-exposed pine trees; in the afternoon, the females deposit their eggs individually on needles which are always in the close vicinity of eggs deposited by the pine beauty, *Panolis flammea* D. SCH. Since the embryo in the egg is already practically fully developed, the larva hatches immediately after egg deposition and remains attached by its abdomen to its cover. It remains at this stage for some days, then it fastens itself using a liquid lime drop to a caterpillar of the pine beauty and immediately bores into its body. The parasitized caterpillar dies, as a rule before pupation at which point the larva of *E. rudis* FALL. crawls out, drops to the ground and pupates in the litter. The females are very fertile: each female deposits up to 900 eggs. Although the species has only one generation per year,

the importance of this tachinid-fly is considerable mainly during outbreaks of *Panolis flammea* D. SCH. In the 1930's *E. rudis* FALL. reduced the population density of the pine beauty in Slovakia by 65 %.

*Agria affinis* FALL. is a smaller species, 6 to 8 mm long; it is bluish grey to grey-black, with pronounced longitudinal stripes on the thorax and with alternate light and dark spots on the abdomen. The wings are slightly brown at the root. The female deposits up to 500 eggs. A small funnel space is developed around the hole through which the hatched larva penetrates the caterpillar body and allows air to enter. First the larva bores into the host body and mainly consumes the ligament of fat at the place where the air tubes branch near to the stigma as shown in Fig. i. The puparium is, like those of other tachinid-flies, chestnut-brown, slightly bright and barrel-like.

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